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Elektor Electronics

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32 48 54 58

SPECIAL FEATURE: Power supplies
MIDI control unit
Practical filter design
FAX interface for Atari ST
Third-generation CD players
Automotive wiring systems
Development system for M6805
NEW SERIES FOR NOT-SO-EXPERIENCED CONSTRUCTORS

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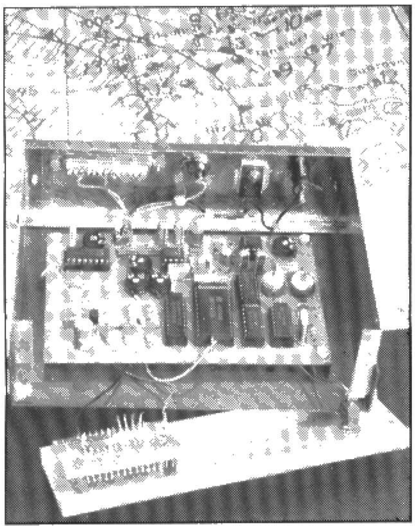
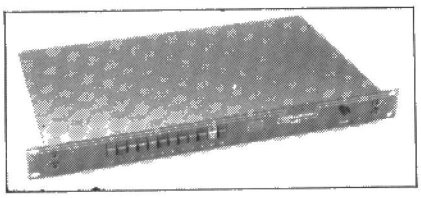
Number 163

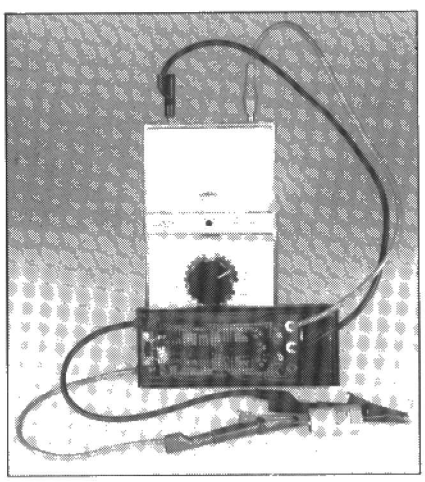
CONTENTS



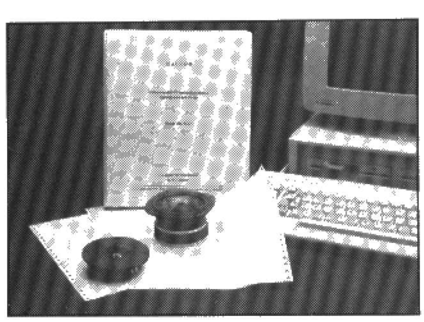
Facsimile interface for Atari ST
p. 12



MIDI control unit
p. 20



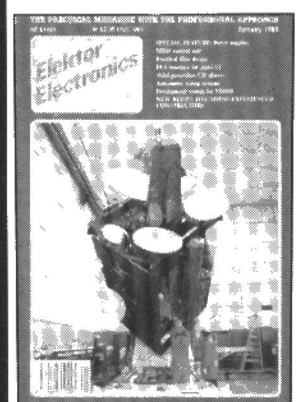
Low-budget capacitance meter
p. 54



CALSOD, a loudspeaker design package
p. 62

In next month's issue:

- Special feature: Computers
- Intermediate project: Darkroom timer
- Wide-band amplifier
- VHF receiver
- Car service module



Front cover

The Olympus thermal model in the satellite assembly hall of British Aerospace. Olympus 1, the world's largest and most powerful civil three-axis stabilized telecommunication satellite, has already completed solar simulation tests and is now undergoing final environmental testing prior to launch on Ariane III in a few months' time. Olympus 1 is 2.9 m wide, 5.6 m long, and has a solar array of over 25.6 m^2. It has been built under contract to the European Space Agency. It carries a 20-30 GHz payload, suitable for video teleconferencing and other business applications.

Elektor Electronics
A Wolters Kluwer Company
Editor/publisher: Len Seymour
Personal Assistant: L. Vousden
Technical Editor: J Buiting
Advertisement executive:
Pauline O'Rourke

Editorial offices:
1 Harlequin Avenue
BRENTFORD TW8 9EW
England
Telephone: 01-847 2618 *(National)*
or +44 1847 2618 *(International)*
Advertising: 01-847 2619
Telex: 917490 (elektr g)
Fax: 01-847 2610

European offices:
Postbus 75
6190 AB BEEK (L)
The Netherlands
Telephone: +31 4490 89444
Telex: 56617 (elekt nl)
Fax: +31 4490 70161

Overseas editions:
Publitron Publicacoes Tecnicas Ltda
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Editor: Jeremias Sequeira

Elektor sarl
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Editors: D R S Meyer;
G C P Raedersdorf

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Editor: E J A Krempelsauer

Elektor EPE
Karaiskaki 14
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Editor: E Xanthoulis

Elektor Electronics PVT Ltd.
Chhotani Building
52 C, Proctor Road, Grant Road (E)
Bombay 400 007 — India
Editor: Surendra Iyer

Elektuur B.V.
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Editor: P E L Kersemakers

Electro-shop
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Lasbella Chawk
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Ferreira & Bento Lda.
R.D. Estefânia, 32-1°
1000 Lisboa — Portugal
Editor: Jeremias Sequeira

Ingelek S.A.
Plaza República Ecuador
2-28016 Madrid — Spain
Editor: A M Ferrer

Electronic Press AB
Box 63
182 11 Danderyd — Sweden
Editor: Bill Cedrum

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GALLIUM-ARSENIDE: A BRIGHT FUTURE?

Mainly because of the needs of the satellite TV business, but also those of the automobile industry, the demand for gallium-arsenide (GaAs) devices is growing at a rate not foreseen by many only a year or so ago. Pundits now reckon that the world market for GaAs devices will be worth in excess of £2 billion by 1992. The main requirements will be for monolithic microwave integrated circuits (MMICs), field-effect transistors (FETs), and high electron-mobility transistors (HEMTs).

Gallium-arsenide devices have some important advantages over silicon devices. First, they exhibit far greater electron mobility, which means that considerably faster circuits can be realized than with silicon. Second, they have far better thermal stability and greater resistance to radiation, which is of particular importance for the production of very fast and highly integrated memories.

On the other hand, silicon has better uniformity, purity, and surface smoothness, which results in better control, and thus greater efficiency.

As far as the state-of-the-art is concerned, much larger and more complex ICs can at present be fabricated with silicon. In general, gallium-arsenide technology is still well behind silicon technology, but the industry expects that it will have caught up by the early to mid 1990s.

From this, it is clear that the applications for GaAs devices will remain, at least for the time being, in those areas where the physical properties of GaAs are superior to those of silicon. These areas include the military sphere, aerospace industry, aviation, satellite television, and automotive engineering. Initially, the use of gallium-arsenide will be confined to small and medium scale ICs, but in the not too distant future it will also be possible to use the material for VLSI circuits.

The United Kingdom, through Plessey, has a good lead in Europe in GaAs technology—in fact, there is no other European supplier. But competition from Japan and the USA is strong. Such an important lead is, of course, worth preserving and it is, therefore, encouraging that the Government has recently authorized a £25 million GaAs research programme.

There are, however, quite a few opponents to the GaAs research programme who say that this money would be better spent on research into silicon technology. Indeed, a number of these researchers believe that within a relatively short time silicon circuits will have been developed for speeds up to 25 GHz. Not unnaturally, many industry insiders take a very sceptical view of these beliefs.

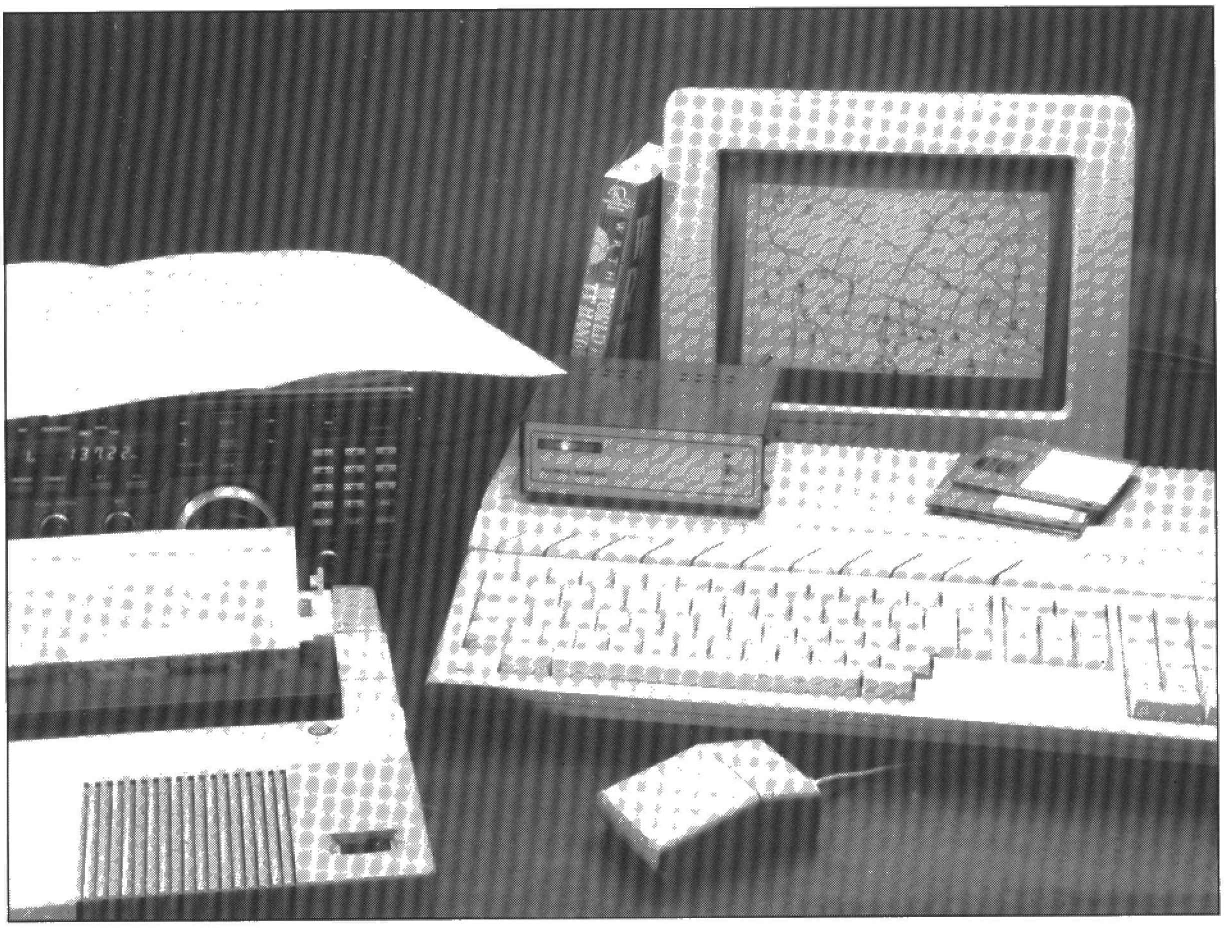
The government programme for GaAs research has staunch supporters, among them the chairman of BICC, Sir William Barlow. During a recent lecture at the Institute of Electrical Engineers, Sir William called for a vast fibre-optic cable network across the UK for the distribution of satellite TV and data services. Such a scheme would provide a massive demand for GaAs devices for use in the necessary decoders and allied equipment. It would also create many thousands of jobs over a long period. Alas, it is only a plan that will probably never come to fruition owing to the absence of firm, co-ordinated policies.

FACSIMILE INTERFACE FOR ATARI ST

Stop press: Archimedes program also available

by P. Neufeld DB9JG

Are you interested in receiving weather charts and press photographs from all over the world? Here is a simple-to-build interface that works in conjunction with an Atari ST computer running a GFA-BASIC program.



Radio facsimile transmissions are fairly simple to decode and convert to legible documents. The information transmitted is composed of picture elements (pixels), whose relative intensity on the black-to-white scale is recorded and translated in frequency. Most facsimile systems based on electromechanical apparatus work with a centre frequency of 1900 Hz, while maximum white and black correspond to frequency shifts of +400 Hz and −400 Hz respectively. All-electronic facsimile systems use other centre freqencies and shifts, e.g., ±2400 Hz and ±1600 Hz. In the modernized fax system, synchronization of the picture at the receiver side is achieved with start and stop tones, which are frequency-modulated on to a data tone. Typical start and stop frequencies are 300 and 450 Hz.

In an electromechanical facsimile receiver, a horizontal drum with a sheet of electrolytic or photosensitive paper secured on it revolves at a precisely regulated speed. A stylus is fed with the decoded information, and shifts from the left (top of picture) to the right (bottom of picture), under the control of a synchronization circuit. This basically simple process can be simulated by a computer loading digitized pixel intensity data in a screen memory. As a useful extension, received pictures can be written to disk, and/or dumped to a printer to obtain hard copy. All of this is possible with the present interface, which operates in conjunction with a menu-driven program. A good-quality shortwave receiver with a BFO (beat frequency oscillator) function, and an Atari 520/1040 ST monochrome computer system with printer, are also required. Provided a suitable decoding program is available, the interface described here is also be usable for other computers than the Atari. This is because it provides a fairly simple-to-use serial output signal with digital swing (5 V_{pp}).

Hardware: facsimile interface

The circuit diagram of the basic version of the facsimile interface is given in Fig. 1. The fax signal taken from the external loudspeaker or headphone connection on the SW receiver is fed direct to the input of phase-locked loop (PLL) IC_1. This comprises a linear VCO, whose output signal (at pin 4) is fed to one of the inputs, pin 3, of an internal phase comparator. The other phase comparator input, pin 14, is driven with

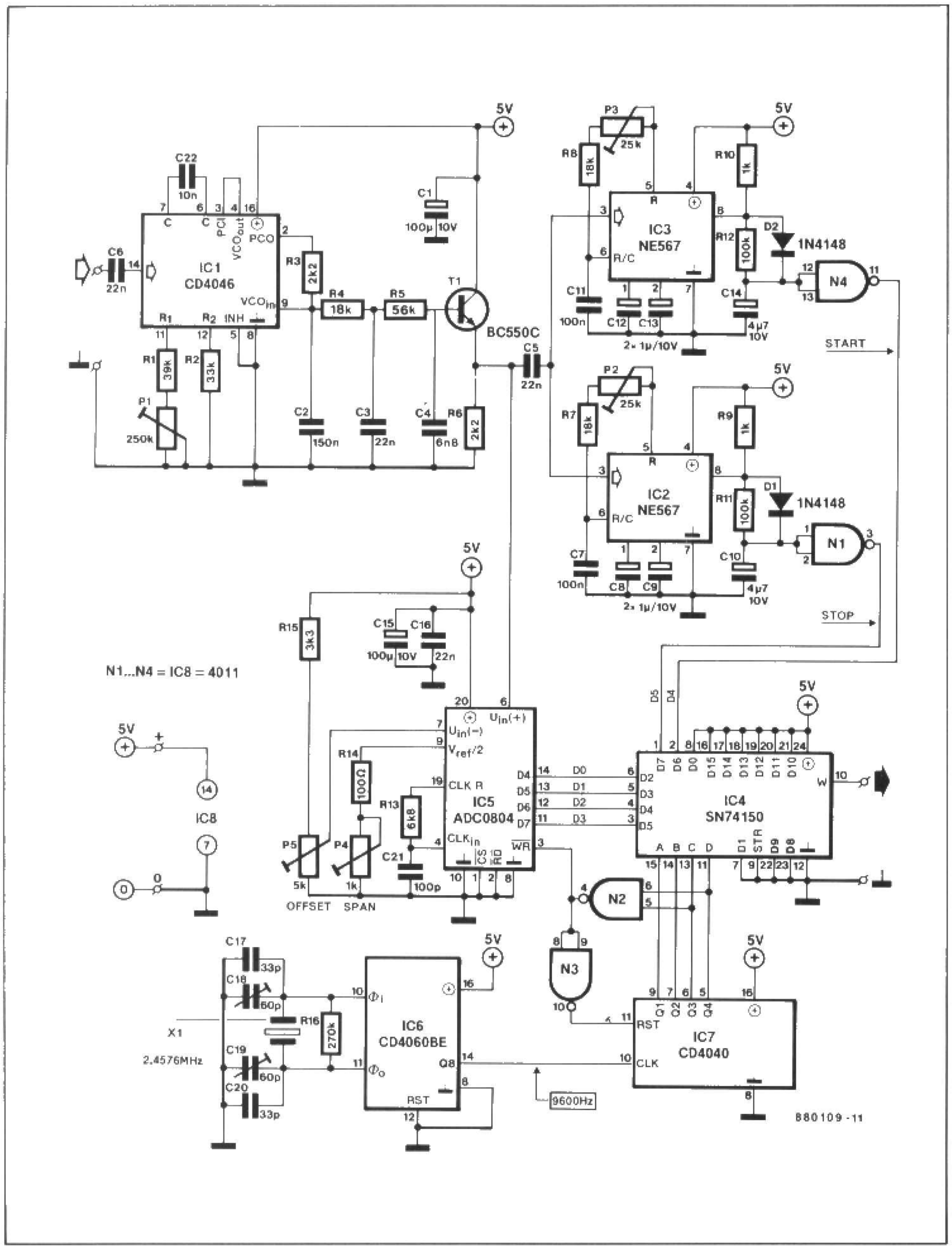


Fig. 1. Circuit diagram of the facsimile interface for Atari ST computers.

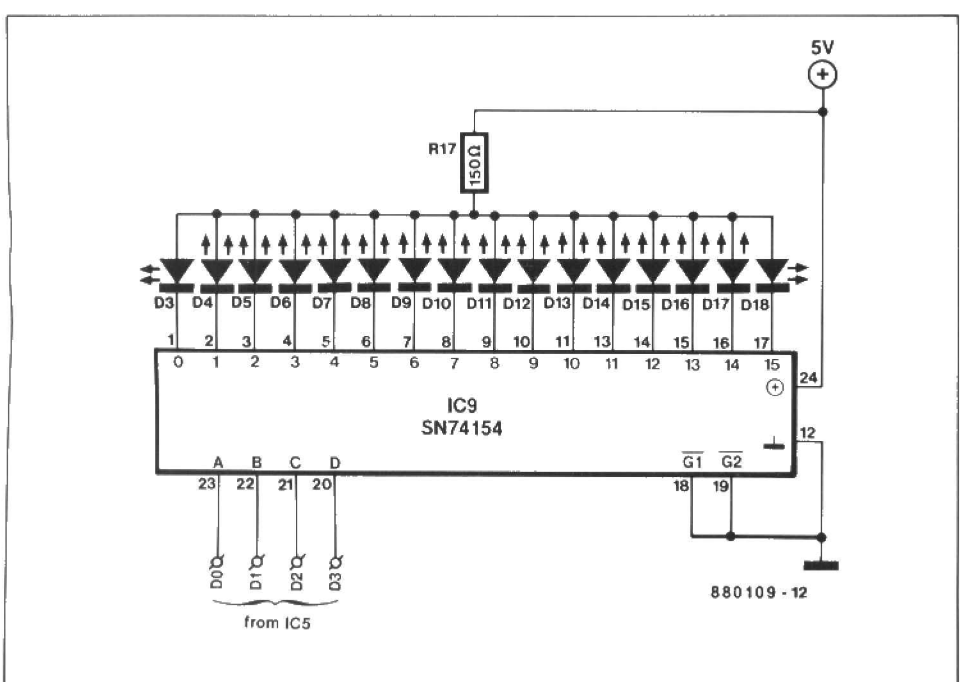


Fig. 2. Optional ADC drive indication based on a LED scale.

the AF signal from the SW receiver. The error signal at the phase comparator output (pin 2), is filtered in loop low-pass R_3-C_2, and fed back to the VCO input (pin 9). The error signal is thus a measure of the deviation from the VCO centre frequency, determined by C_{22}, (P_1+R_1) and R_2. The PLL error signal is first passed through low-pass R-C filter R_4-C_3-R_5-C_4 before buffer T_1 divides it between three circuits.

C_5 feeds the signal to two PLL tone decoders Type NE567, which detect the start (IC_3) and stop (IC_2) tones. These are not subject to much attenuation in the low-pass filter and are, therefore, available as ripple at the emitter of T_1. A preset is provided to enable the centre frequency of the tone decoder to be set to that of the start tone (P_3) or the stop tone (P_2). Examples of practical start and stop tone frequencies are 300 Hz and 450 Hz respectively. The output, pin 8, of each tone decoder goes low when the PLL locks onto the incoming signal. The capture range is about 25 Hz. When the PLL is out of lock, its output pulses are rectified by D_2-C_{14} (D_1-C_{10}) to maintain a logic low level at the output of the associated inverter, N_4 (N_1). When detected, the start and stop tones are translated in logic high levels applied to inputs D6 and D7 of IC_4.

The direct voltage provided by T_1 has a span of about 1 V to 3.75 V. The instantaneous value represents the intensity of each pixel. The emitter voltage of T_1 is fed to the input of analogue-to-digital converter (ADC) IC_5. This is an 8-bit, microprocessor-compatible digitizer, of which only the 4 most significant bits, D4 through D7, are used to a give a maximum of 16 possible shades of grey. The frequency of the on-chip clock oscillator in control of the successive approximation A-D conversion process is determined by external components R_{13} and C_{21}. A span adjustment, P_4, and an offset adjustment, P_5, are provided to ensure optimum matching to the range of the analogue voltage supplied by T_1. In practice, the presets serve to define the shades of white, grey and black that correspond to particular tone frequencies in the fax signal.

The quartz-controlled oscillator and frequency divider built around IC_6 and IC_7 are of conventional design. Four output lines on IC_7 are used for clocking multiplexer IC_4, which functions as a parallel-to-serial converter. It accepts the 4-bit digitized fax data (D0-D3), start and stop bits (D4; D5), and 6 hard-wired levels (D0-D1 and D8 through D11). This data is shifted out in inverted form to the computer as a 12-bit serial dataword (IC_7 is reset when its outputs Q3 and Q4 are simultaneously logic high). The data rate on the output line to the computer is 9600 bits/s. Although the out-

put of the facsimile interface does not supply a true RS232 signal, most computers will not have difficulty reading it correctly on the serial port.
The structure of the serial dataword is shown in Fig. 3. Bit 0 is always logic low (D0 input of 74150 tied to +5 V). Similarly, bit 1 is always logic high (D1 input tied to ground). Then follow the 4 fax bits (LSB first). Bits 6 and 7 are the start and stop bits, respectively. The fax data in the example is 1010 (intensity 10/16 of white). At the 12th clock pulse, counter IC_7 is reset by N_2-N_3. ADC IC_5 receives a $\overline{WR}$ pulse at pin 3, and a new pixel is processed.

Figure 2 shows the circuit diagram of an optional tuning aid. A 74154 4-to-16 demultiplexer is driven with the digitized

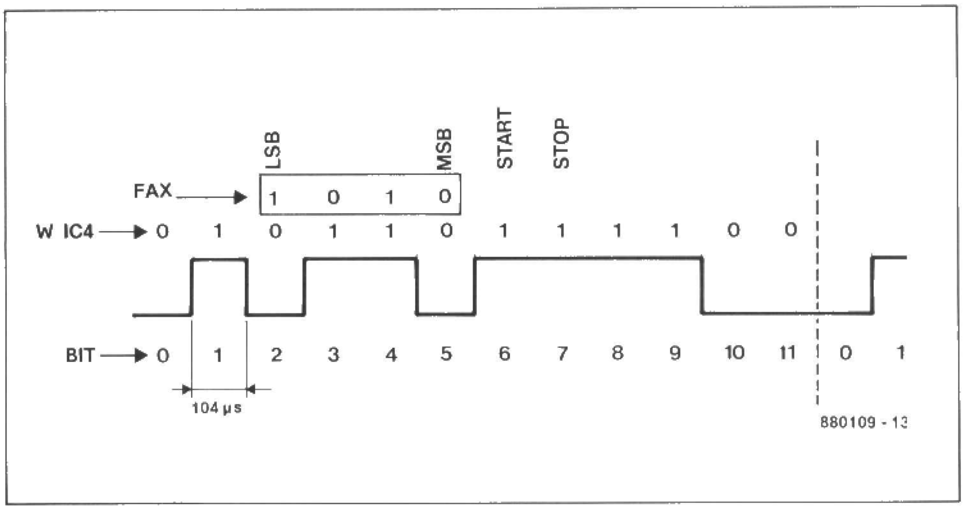
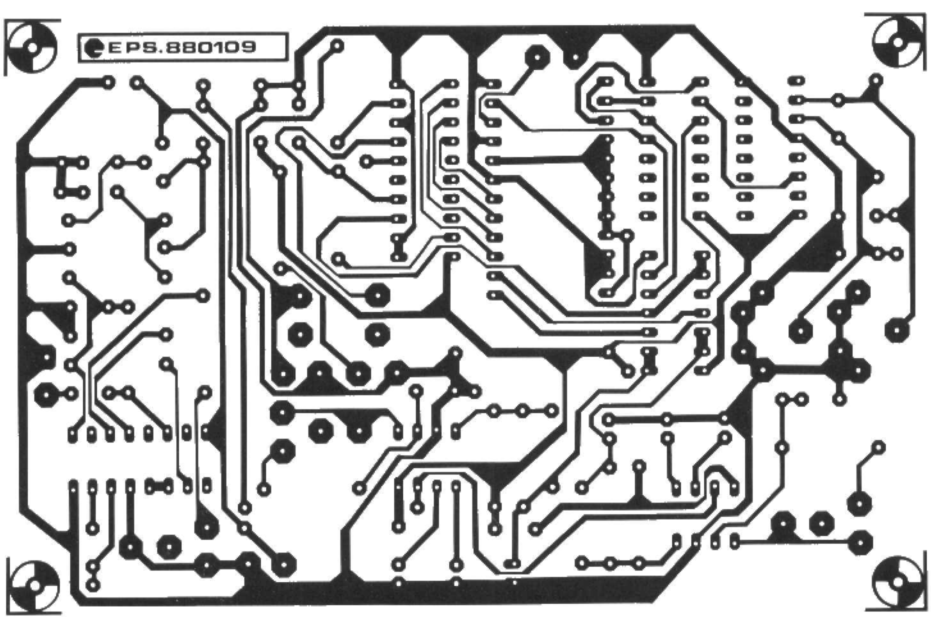


Fig. 3. Serial output signal supplied by the fax interface. The signal has a swing of 5 V_{pp} and is TTL-compatible.



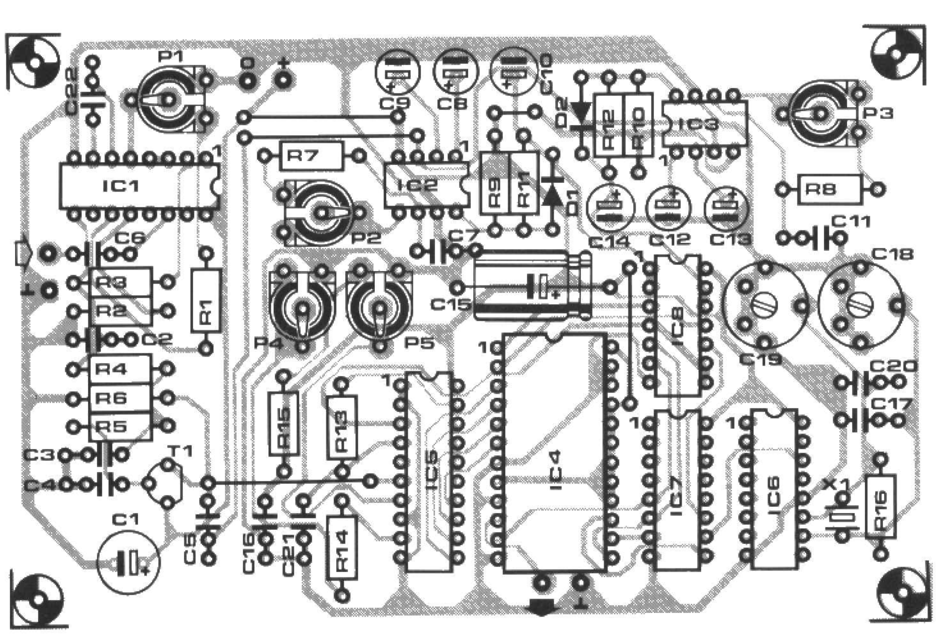


Fig. 4. Single-sided printed-circuit board for the facsimile interface.

Parts list

Resistors (±5%):
R1 = 39K
R2 = 33K
R3 = 2K2
R4;R7;R8 = 18K
R5 = 56K
R6 = 2K2
R9;R10 = 1K0
R11;R12 = 100K
R13 = 6K8
R14 = 100R
R15 = 3K3
R16 = 270K
P1 = 250K preset H
P2;P3 = 25K preset H
P4 = 1K0 preset H
P5 = 5K0 preset H

Capacitors:
Note: Electrolytic types are radial unless otherwise noted. Specified working voltage is minimum.
C1 = 100μ; 10 V
C2 = 150n
C3;C5;C6;C16 = 22n
C4 = 6n8
C7;C11 = 100n
C8;C9;C12;C13 = 1μ0; 10 V
C10;C14 = 4μ7; 10 V
C15 = 100μ; 10 V; axial
C17;C20 = 33p
C18;C19 = 60p trimmer
C21 = 100p
C22 = 10n

Semiconductors:
D1;D2 = 1N4148
T1 = BC550B
IC1 = CD4046
IC2;IC3 = NE567
IC4 = 74150
IC5 = ADC0804
IC6 = CD4060BE
IC7 = CD4040
IC8 = CD4011

Miscellaneous:
X1 = quartz crystal 2.4576 MHz.
PCB Type 880109 (see Readers Services page).

pixel intensity data, and lights 1 of 16 LEDs to indicate relative tone frequency.

The fax interface is powered from a regulated 5 V source. A standard power supply, consisting of a mains adaptor (8-10 VDC), and a well-decoupled 7805 three-pin voltage regulator in standard configuration is adequate. Power consumption of the interface, exclusive of the optional display, is about 60 mA.

Construction and setting up

Construction of the interface is straightforward on the printed circuit board shown in Fig. 5. First fit the 5 wire links, so that these are not overlooked later. All electrolytic capacitors, except C_{15}, are radial types, whose orientation on the board should be ascertained before they are soldered in place. The optional ADC drive indicator and LED read-out are built on a small piece of prototyping board. This unit is fitted such that the LEDs protrude from the front panel of the metal enclosure.

The 5 V regulator may be fitted onto the rear panel of the enclosure. A small socket as used in cassette recorders may be used for feeding in the unregulated voltage supplied by the mains adaptor. Do not forget to decouple the input and output of the 7805 with the aid of small tantalum capacitors.

The input of the fax interface can be any suitable AF socket (e.g. a jack or phono type); the output a length of 2-wire cable connected to a female D25 connector (pin 7: ground; pin 3: serial signal; connect pin 8 to 20, and 5 to 6).

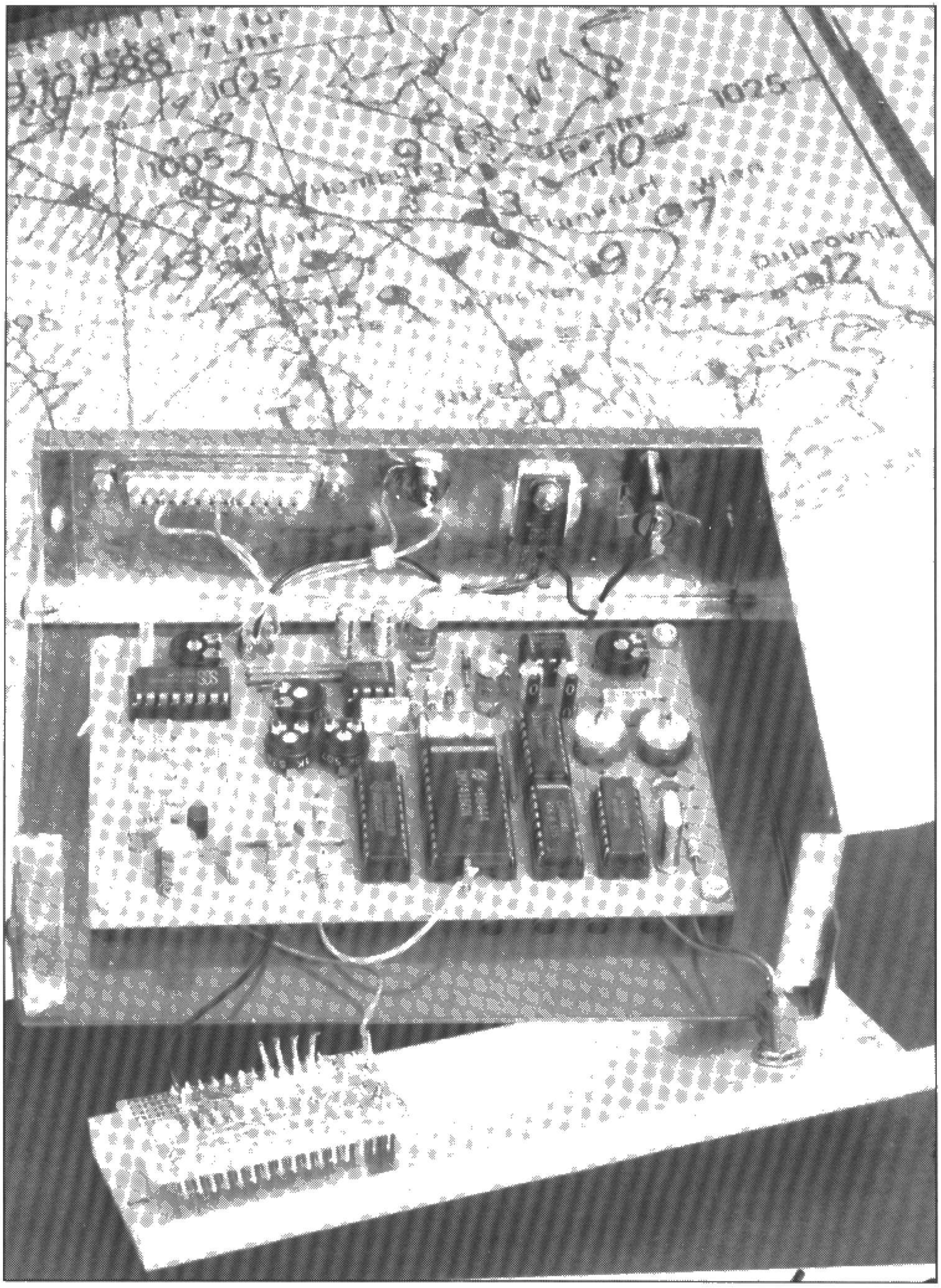


Fig. 5. Prototype of the facsimile interface with ADC drive read-out, housed in a small metal enclosure.

Setting up:

The fax interface is aligned with the aid of a sine-wave generator, a frequency meter, an analogue voltmeter and an oscilloscope.

Before applying 5 V, set all presets and trimmers to the centre of their travel. Short-circuit the AF input of the interface. Disconnect C_5 from the emitter of T_1. Apply power, check the current consumption, and verify the presence of the supply voltage at a number of points in the circuit.

Connect the frequency meter to pin 3 of IC_1, and adjust P_1 for a reading of 3.9 kHz.

Connect the frequency meter to pin 9 of IC_6, and adjust C_{18} (and, if necessary, C_{19}), for a reading of 2457.6000 kHz. Alternatively, if your frequency meter does not reach up to 10 MHz, connect it to pin 10 of IC_7, and adjust the trimmer(s) for a reading of 9600 Hz.

Connect the frequency meter to pin 6 of IC_3, and adjust P_3 for a reading of 300 Hz. Do the same for IC_2: set P_2 for a reading of 450 Hz.

Connect the output of the sine-wave generator to the free terminal of C_5, and apply a test signal of about 500 mV_{pp}. Connect the (DC-coupled) oscilloscope to pin 8 of IC_3. Tune the generator between 200 Hz and 500 Hz, and check that pin 8 goes low at 300 Hz ±15 Hz (approximately). Do the same for the stop-signal decoder (IC_2; 450 Hz ±15 Hz). Disconnect the generator from C_5, and connect this capacitor to the emitter of T_1.

Use the scope to check the presence of count pulses at the A-B-C-D inputs of IC_4. Also check that IC_5 receives $\overline{WR}$ pulses at pin 3 (these pulses are very short, and you may have to turn up the scope's intensity control to see them).

Connect the voltmeter to pin 9 of the ADC, IC_5, and set P_4 for a reading of 250 mV. Then set P_5 for a reading of 1.50 V measured at pin 7. Remove the short-circuit at the AF input of the fax interface, and connect the sine-wave generator. Apply about 1 V_{pp}. Connect the oscilloscope to pin 2 of the PLL, IC_1. Tune the generator to 3.8 kHz, and verify that the pulses displayed are steady. Then vary the generator's output frequency between about 3.6 kHz and 4.7 kHz. The PLL should remain locked onto this input signal. This is indicated by the changing duty factor of the VCO control signal at pin 2. A hysteresis of about 150 Hz will be noted at the band edges. Simultaneously measure the emitter voltage of T_1: the PLL lock range should correspond to a voltage span of about 1.0 V to 3.75 V. Between these extremes, the voltage should track smoothly with the input frequency.

The VCO centre frequency is set relatively high here to achieve sufficient ripple suppression on the control signal. Most modern SW receivers have a wide-range BFO, and should not have diffi-

culty producing signals of frequencies up to about 4.5 kHz. It is possible to redimension the PLL for a centre frequency of, say, 1800 Hz and a lock range of 1.45 kHz to 3.5 kHz, by fitting the following components: R_2=100 kΩ; C_2=22 nF; C_4=10 nF. While experimenting, it should be borne in mind that VCO frequency and lock range depend strongly on the make of the 4046 PLL chip. In the prototype, good results were obtained with SGS's HCF4046.

The program

The facsimile decoder program for the disk-based, monochrome, Atari 520/1040 is written in GFA-BASIC. It enables the user to select any of three facsimile standards: WEFAX (weather chart fax) at two speeds, or DPA (Deutsche Presse Agentur), which differ in respect of picture orientation. Further, the menu prompts the user to select the number of shades of grey, up to a maximum of 7. Hard-copy and disk storage/retrieval functions are also availabe.

In the main program, 320 of the 400 pixels in each fax line are stored in memory and displayed on the lower two lines of the screen. Following this operation, the screen is scolled up by two lines. The next line of fax data is not processed in view of program speed considerations. To achieve synchronization during picture transmission, the screen can be shifted to the left or right with the aid of the cursor keys. The program is halted either by reception and recognition of the stop signal, or by pressing the F1 key. The building of the picture on screen recommences after recognition of the start signal. The 'wait for start' subroutine can be left by pressing any key on the keyboard. When F2 is pressed, the program halts until any key is pressed (pause function). The program is ended by pressing the escape key. DIN A3-size hard-copy on a dot-matrix printer may be obtained by holding down the alternate and help keys simultaneously.

The 7 available shades of grey are simulated on the screen by means of a dot-pattern array, built by the program after initialization.

The screen menu is self-explanatory and requires no further detailing here. The listing of the decoder program has a large number of comment lines to aid programmers in analyzing the operation, and making alterations or improvements.

Practising

The fax decoder is critical in respect of receiver tuning, and some experience is, therefore, essential. Initially, start with recording on tape of strong meteorological fax stations (many can be found between 100 kHz and 150 kHz). Play these recordings back into the interface, selecting only 2 shades of grey with the aid of the program menu. It will be found that the receiver's tuning and BFO have to be set such that the output signals are of relatively high frequency (3.5 to 4.5 kHz). Photofax signals (DPA mode) can be used for setting the offset and span presets (P_4-P_5) in the interface, until the picture quality is optimum. The span and offset voltages mentioned in the alignment procedure are intended as guidance only.

Stop press: superb photofax pictures on the Archimedes!

Just before this issue of *Elektor Electronics* was going to press a program was developed that enables the Archimedes computer to work with the facsimile interface. Thanks to its ability to display true shades of grey, the Archimedes offers far better resolution of photofax pictures than the Atari. Figure 6 how the interface is connected to the computer to ensure correct voltage levels at the serial input port. The program for this computer is available on disk as order number ESS103. Ordering details are the same as those for the Atari disk, ESS102.

The program is available on disk only under reference number ESS102. To obtain this, send the following to our Brentford office:

- a formatted 3½-inch Atari diskette;
- payment as detailed on the Readers Services page;
- a stamped, addressed return envelope (overseas readers please include 3 IRCs, or £1.00 remittance, for return postage).

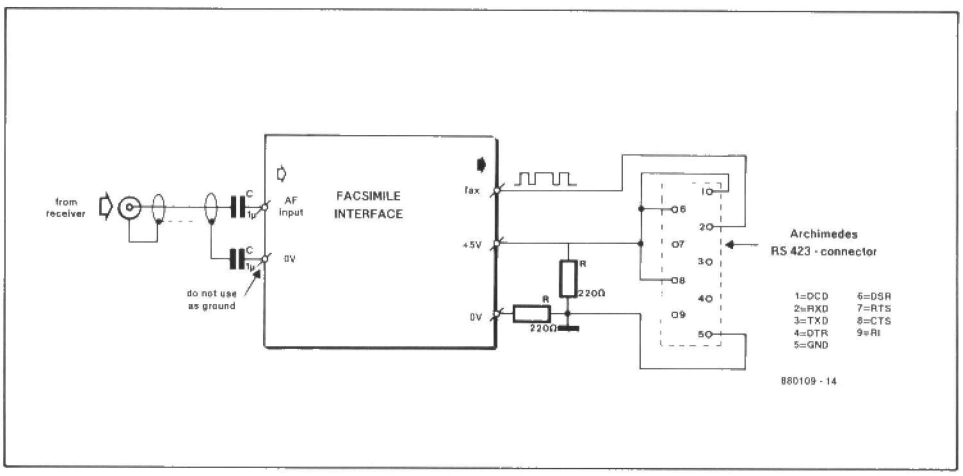


Fig. 6. Connection of the interface to an Archimedes computer.

NEWS

Anglo-Swedish telephone service

Mercury Communications and the Swedish Telecommunications Administration are joining forces in the provision of switched telephone and other services. Sweden has recently introduced legislation that further liberalizes the telecommunications market and allows for the gradual separation of operational and regulatory functions.

The Mercury-Sweden route, which will open early this year, will be all digital and will use the new UK-Denmark 4 fibre optic cable that has just been commissioned.

IBC beats al records

IBC88 was even larger than IBC86 which in itself was a record-breaking convention. There were over 20,000 participants from 62 countries at the International Broadcasting Convention held at Brighton from 23 to 27 September last. The well attended Technical Programme generated interesting, informed and lively discussions with 114 papers presented by authors from 14 countries. As was expected, the chief interest was in High Definition Television—HDTV, digital handling of television signals and satellite broadcasting; the keynote was set in the opening session with a discussion of HDTV. Other aspects of broadcasting were not neglected, however, and the Technical Programme as a whole was one of the fullest and most varied ever.

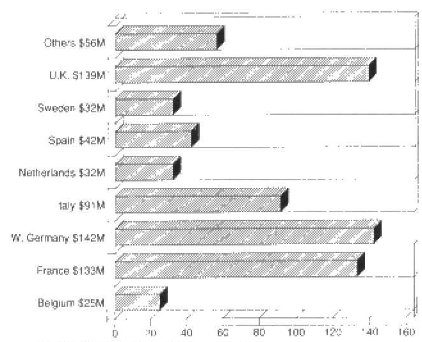
The IBC88 award was presented to Professor Henri Mertens, Assistant Director, Technical Centre, of the European Broadcasting Union (EBU), in recognition of his major contribution to broadcasting over a period of many years.

POWER SUPPLIES: AN OVERVIEW

by R.J. Hardy, MSc

The UK power supply business is expanding in line with market needs. The total power supply market in the UK is currently worth in excess of £235 million and is expected to grow to nearly £400 million by 1992. The markets in West Germany and France show a similar picture: that in West Germany is slightly larger, and that in France somewhat smaller, than that in Britain. The total European power supply market in 1987 amounted to £1.12 billion and this is expected to grow to £1.62 billion by 1992. The fastest growing sector of the power supply market is that for switch-mode types, but that for uninterruptible versions is not far behind. The latter is a direct consequence of more and more businesses realizing that loss of vital data caused by power failure could land them in serious trouble. It should be noted that a UPS is NOT synonymous with a stand-by power supply: this kind of confusion between the two has already cost a number of users dearly (because no stand-by power supply can switch fast enough in the event of mains power failure).

UPS & POWER CONDITIONING EQUIPMENT MARKET IN WESTERN EUROPE - 1988



Another noteworthy aspect of the power supply market concerns the exaggerated claims some producers give to switch-mode power supplies. There is no doubt that these types have definite advantages over linear types in some situations, but it is equally true that they are NOT always the right choice for a given application. In fact, it is probably true to say that in the majority of applications they are out of place.

Over the past few decades, the design of power supplies has made consistent and rapid progress. There are a number of reasons for this. One of these is the ever-increasing demand for a wide variety of power supplies for an ever larger number of applications. Another one is the continuing improvement in power component performance. A third is the availability of new components designed to meet specific requirements.

Basically, there are only two types of power supply: AC and DC operated, but these may be sub-classified into many different categories. For instance, classified by the kind of conversion, there are AC-to-DC, AC-to-AC, DC-to-AC, and DC-to-DC versions. Any of these versions may, in its turn, be of the step-down (US:buck) or step-up (US:boost) kind. Added facilities give rise to names like uninterruptible power supplies (UPSs). DC-to-AC types are often called inverters, and AC-to-DC types, converters.

AC-to-DC power supplies are the most common and usually work direct from the mains supply. They are used in countless domestic and industrial apparatuses.

AC-to-AC types are often rotary devices, especially in the case of power step-up versions. Some AC-to-AC types merely provide isolation from the mains.

DC-to-AC converters are used where an AC equipment (portable drill, TV) has to operate from a DC source. The DC-to-AC conversion is normally accomplished by pulse-width modulation (PWM) or resonant oscillation. There are four common configurations PWM inverter: fly-back, push-pull, half-bridge, and full-bridge.

DC-to-DC power supplies normally consist of an inverter followed by a rectifier. Since the inverter is operated at a very high frequency, the ripple on the output voltage is removed easily by means of small filters.

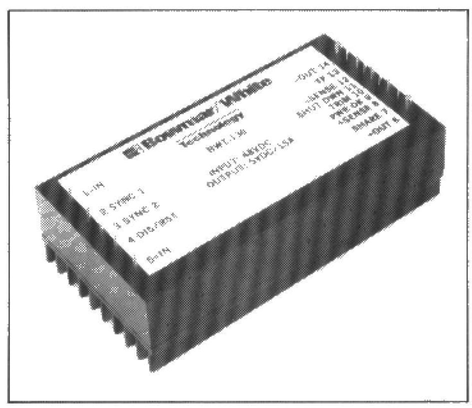
Bi-directional power supplies are used in applications such as battery charging and discharging.

Emerson Electric's AP70X Series of 3-phase uninterruptible power supplies is said to have fewer active components than most comparable equipment. The power systems in this series have a battery supply that can be made to suit individual customers' requirements.

Designed for use within the computer room or office suite, the series comprises six models in either single-module or multi-module systems. Output ratings range from 30 kVA to 700 kVA and output voltages are 220/380 V or 240/415 V 50 Hz. Frequency tolerance is nominally ±0.1% in free-running mode. Power switch on is from 20% to 100% in 15 seconds.

Special features include a pulse static switch that facilitates branch fuse clearance while output power is maintained, and a low-energy thyristor turn-on method of static isolation that ensures that any faulty UPS module in a multi-module redundant system can be isolated from the load while power to the load is maintained.

Emerson Electric Ltd • Elgin Drive • SWINDON SN2 6DX.



Bowmar/White Technology's Model BWT-130 is a very compact 75-watt switch-mode DC-to-DC converter designed to convert an unregulated 48 V DC input into a well-regulated 5 V DC output for loads up to 15 A.

The key parameters are a guaranteed minimum efficiency of 80%, a 5.7 W/in^3 power density, the ability to provide automatic current sharing between parallel-connected supplies, and a capability to detect reduced output voltage or a complete failure of the primary power switching.

The BWT-130 will handle loads over the full range of zero to full power and, in the event of short circuits or overloads, there is a primary-current limiter to prevent supply damage.

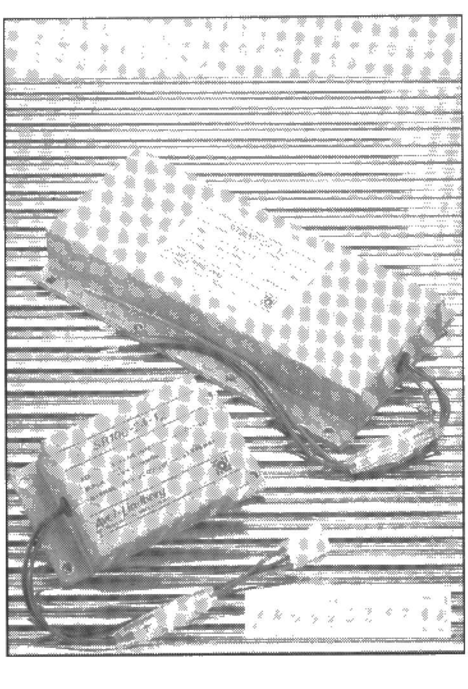
Load regulation is $<0.2\%$. Line regulation is $<0.1\%$. Other features include overvoltage protection, current limiting to 18.8 A (max), minimum input-to-output isolation of 2,000 V DC, and a typical no-load power consumption of just half a watt. Operating temperature with natural convection is -20 °C to $+60$ °C.

Bowmar/White Technology • 4246 E. Wood Street • Phoenix • Arizona 85040 • USA.

STC Instrument Services has an agreement with Prism Electronics to supply that company's wide range of programmable power supplies.

STC Instrument Services • Dewar House • Central Road • HARLOW CM20 2TA.

vel-Lindberg are the first UK transformer manufacturer to have three ranges of toroidal transformers 'recognized' by the Underwriters Laboratories—UL—as meeting the construction and performance of toroids to the Standard for Safety for Speciality Transformers UL506. This 'first' to be able to use the coveted UL recognition means that where a customer requires toroidal transformers for use in the power supply of a UL recognized electronic equipment he will be able to refer to the Avel UL 'recognition' as a matter of course and know that these toroids are, and will continue to be, manufactured to the high standards demanded by



the specification.

The company also supplies a range of DC Switching Regulators and a range of 'float-mode' uninterruptible power systems.

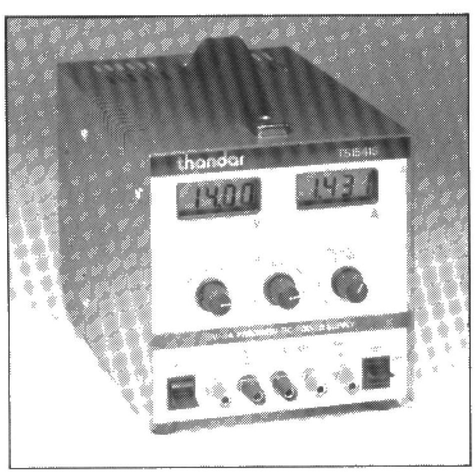
Furthermore, it markets a range of ferroresonant power conditioners that will accept badly malformed AC waveforms (including triangular and square wave) and provide a clean noise-free sine-wave output. This range is designed to ensure clean and stable electrical power (despite mains abnormalities) for computers and other microprocessor-controlled equipment.

Avel-Lindberg Ltd • SOUTH OCKENDON RM15 5TD.

A low cost, easy-to-use, personal power-supply test workstation is available from Interpro Systems. The 'Micro Series' offers a choice of racking systems that make it applicable for testing supplies with powers of virtually any size. The 'Micro Series' can be configured for testing characteristics of circuits during the design stages, go/no-go and functional testing in the production cycle, to repair, maintenance and quality monitoring of power supplies from low-power DC-to-DC converters to 1000 W DC-to-DC mainframe computer supplies.

Three software packages, for any standard AT or XT personal computer, provide the system with great versatility.

Interpro Systems Ltd • Crescent House • 77-79 Christchurch Road • RINGWOOD BH24 1DH.

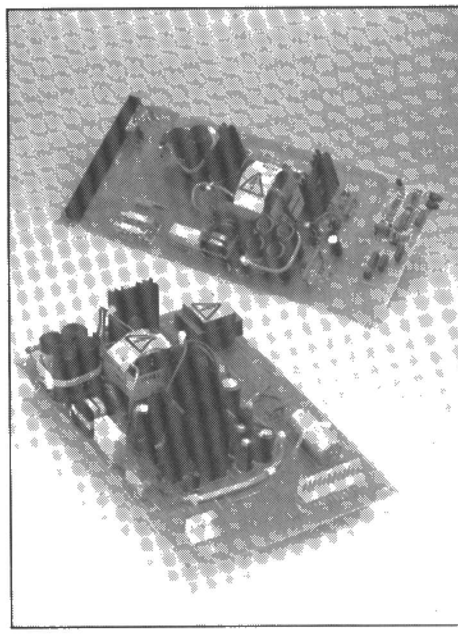


Thandar's TS1541S is a laboratory-quality linear power supply with remote sensing and able to provide 0–4 A at 0–15 V. Dual 0.5 inch, 3.5 digit LCDs simultaneously display output voltage and output current. It operates in constant-current or constant-voltage modes with automatic cross-over.

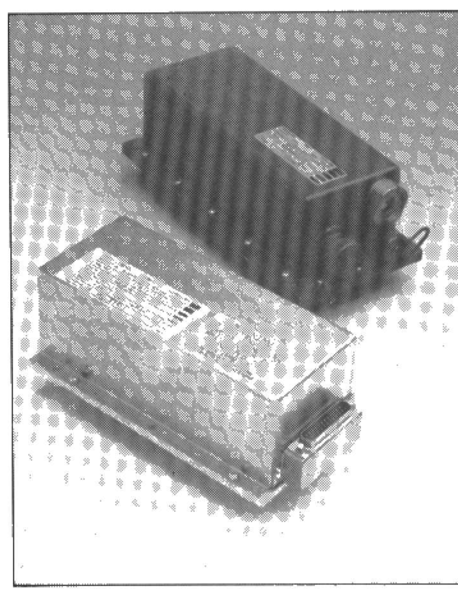
Line and load regulation are better than 0,01%, while noise and ripple are typically <1 mV.

Thandar Electronics Ltd • 2 Glebe Road • HUNTINGDON PE18 7DX.

Intelligence Power Technology, who export their power supplies worldwide, have entered new European markets and beaten Far Eastern competition in the process by designing and building high performance PSUs to individual specification for French distributor Accord Electronique.



Furthermore, the company have recently announced a new range of 250 W supplies. The FET250 Series of multiple output units is aimed at large systems, particularly VME bus and those involving large modems, such as multiplexers and message switches.



Based on the company's established FET200 Series of power supplies, the new range provides fully regulated selected outputs. The new series comprises units that provide 2, 3, 4, or 5 outputs with a wide choice of output currents and output voltages. Supply regulation is better than ±0.5% with input voltages between 96 V and 132 V or between

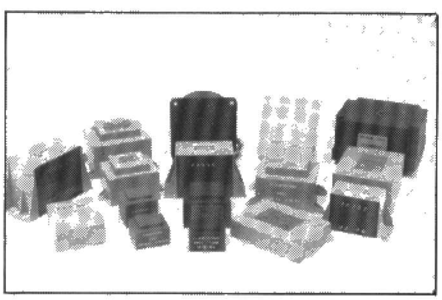
192 V and 264 V 47—440 Hz. Load regulation is generally better than ±1% on all outputs.

Intelligence Technology Holdings • Foredown Drive • PORTSLADE BN4 2BB.

A range of toroidal power transformers from Cotswold Electronics, rated from 30 VA to 530 VA, has been awarded UL 'recognition'. The company were already able to manufacture toroids to the relevant BS, CEE, CSA, DEF, IEC, SEV, VDE, SEMCO, and DEMCO specifications.

The toroids combine modern winding techniques with high-grade insulation in accordance with BS514 Class 2, IEC65 Class 2, and UL506. The construction includes a grain-oriented silicon steel strip tightly wound core, polypropylene core insulation, polyurethane insulated copper wire, double insulation of polypropylene plus polyester tape between the windings, the final winding, and an outer covering of Melinex tape. Specification detail include 105 °C max. operating temperature, 3% secondary voltage tolerance at normal input and full load, a 4.5 kV peak flash test, and 150 mm leads.

Cotswold Electronics Ltd • Unit 1 • Kingsville Road • Kingsditch Trading Estate • CHELTENHAM GL51 9NX.

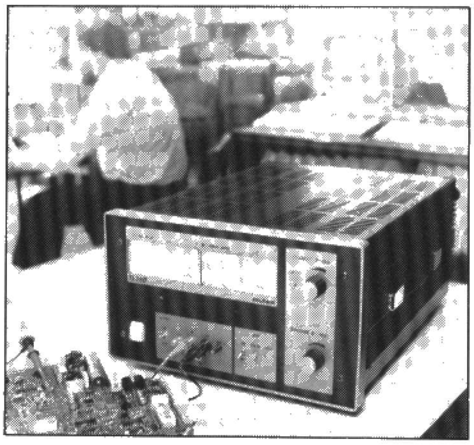


With the introduction of universal voltage (100-120-220-240 V) Low Profile Transformers, Clairtronics now claim to offer the widest stock range of encapsulated transformers available in the UK.

The new range permits worldwide operation from two primary windings and these transformers may, therefore, be used anywhere without the need to specify the domestic supply voltage.

Encapsulated transformers are increasingly used in new power supply designs because they are protected against handling damage and provide a significant increase in long-term reliability. Standard versions include PCB and chassis mounting types and toroidal units for higher power applications. Special designs are supplied to customer requirements. The power range is from 1.2 VA to 130 VA.

Clairtronic Ltd • 93 Whitby Road Industrial Estate • SLOUGH SL1 3DR.



A new series of power supplies from Coutant Electronics for laboratory and test purposes may be controlled remotely via an integral IEEE488 interface. The units are available with a wide choice of active loads to form a complete automatic testing system or to create an accurate system for research purposes. They have floating outputs (maxiam of 600 W and 750 W), versatile programming potential and precision regulation.

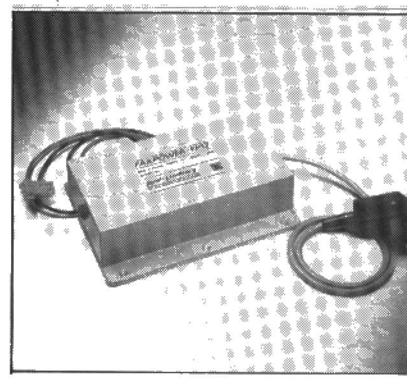
Coutant Electronics Ltd • Kingsley Avenue • ILFRACOMBE EX34 8ES.

Weir Electronics has introduced a single-output OEM switched-mode power supply capable of delivering a stable 5-volt output at load currents up to 300 A. The SMS 1500 00 00 ist the first of the company's range of 1500-watt sources based on an advanced switched-mode regulator. All models include Weir's unique electronic power-factor correction system, which virtually eliminates high-level quadrature current components from the AC input loading; this allows full-power operation from normal 13-A mains sockets, even at the lowest permissible input supply voltage.

The DC output is fully floating with respect to chassis and its voltage is adjustable by an internal preset control between 4.5 V and 5.5 V. Load regulation is <0.4% voltage variation for a change in load from 300 W to 1500 W. Line regulation ensures <0.2% output variation for a change in input level from 265 V to 195 V.

The SMS 1500 00 00 power supply meets the safety requirements of IEC, VDE, CAS, UL, and BS. It also meets international EMC requirements, including those of VDE 0871, Curve B.

Weir Electronics Ltd • Durban Road • BOGNOR REGIS PO22 9RW.



Power to run office type facsimile machines from 12 V or 24 V batteries is derived from a special Faxpower Model FP12/FP24 power unit from Avel-Lindberg.

These power units are designed for maximum reliability and sealed against spray and dirt. Moreover, they are fully impregnated to protect them from vibration and shock normally associated with road vehicles.

Direct written and diagrammatic presentation of information to and from a vehicle by an existing mobile phone is a further step towards the complete mobile office. Avel-Lindberg can supply power units suitable for mobile computers, electronic typewriters, mobile telephones, and Band III communication equipment.

Avel-Lindberg Ltd • SOUTH OCKENDON RM15 5TD.

Some other useful addresses:

ASTEC Europe • 8b Portman Road • READING RG3 1EA (Switch-mode power supplies and DC-to-DC converters)

Fuselodge Ltd • 267 Acton Lane • Chiswick • LONDON W4 5DD (linear and switch-mode power supplies).

Jaytee Electronic Service Ltd • 143 Reculver Road • Beltinge • HERNE BAY CT6 6PL (Transformers).

Jidenco Machines International Ltd • Jidenco House • Vale Road • WINDSOR SL4 5JW (Uninterruptible power supplies).

Powerail Electronics Ltd • 6B Princes Street • DUNSTABLE LU6 3AX (Switch-mode power supplies).

ROHM Corporation • 8 Whatney • IRVINE CA 92718 • USA (DC-to-DC converters).

MIDI CONTROL UNIT Q4

by H. van Bommel

The MIDI control unit described here has been baptized 'Q4' because it can quadruple the possibilities of a MIDI keyboard connected to one or more MIDI-compatible synthesizers or expanders. In other words: it brings *quatre-mains* (four hands) playing in MIDI within reach, and in addition allows quick sound preselections to be made, be it in the course of the musical piece just before a solo, or in between two pieces.

Digital expander, digital sound module, digital synthesizer, digital keyboard, digital effects unit, digital drums, ...it appears that the more equipment is introduced that operates with digital circuits, the fewer keys are left for the player to press. Much new MIDI equipment operates the minute the power cord is connected. But it is wrong to assume that the absence of keys and controls means a reduction of the number of available functions; indeed, the contrary is often true. The unit described here is intended mainly for those who already have experience working with multi-instrument MIDI equipment configurations, or those who would like to learn how to use the MIDI standard when more than one instrument is to be controlled. Irrespective of its actual appearance (casing, keyboard, display), the way it is programmed, or, indeed, its design background, what counts in practice is that the Q4 is a remarkably simple-to-use addition to an available set of MIDI equipment.

Making live playing simpler

The MIDI Q4 unit offers 100 presets, whose function is essentially to actuate and control the bulk of the functions offered by polyphonic and multi-sound equipment, and in addition to facilitate real-time ('live') playing. These presets can be designed and modified quietly at home. Once ready for use, they can be stored in the Q4's memory where they will remain unchanged, if so desired, for up to five years. On the stage, or wherever the musical performance takes place, the programmed presets are immediately available, and can be called up either direct by the keys on the front panel of the Q4, or via the MIDI interface by predefined keys on the master keyboard (see Fig. 1). The preset identification number is displayed on two 7-segment LED displays, and a command string is sent to all connected MIDI equipment. When another preset is needed later in the musical piece — after, say, 16 or 32 beats — the user need only call up the appropriate number.

MIDI CONTROL UNIT Q4

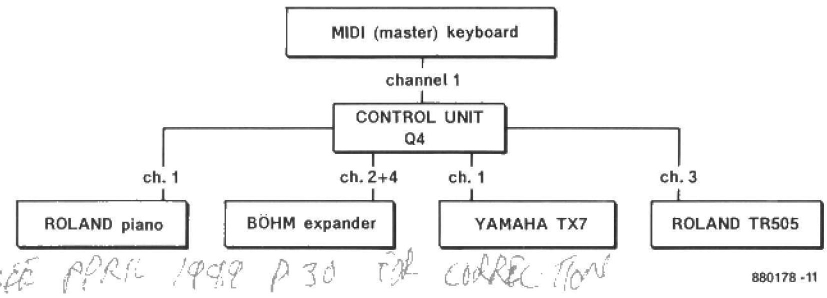
Technical features:

- 100 MIDI presets
- Each preset has 21 parameters capable of performing 3 types of operation:
  a. permanent routeing of MIDI channel 1 to other channels with the aid of 4 rerouteing parameters
  b. instantaneous programming messages on 4 MIDI channels:
  4 parameters for MIDI channel definition
  4 parameters for bank selection
  4 parameters for voice select
  4 parameters for volume select
  c. optional linking of two or more presets
- 1 input for MIDI keyboard (master keyboard possible)
- 4 outputs for MIDI units under control
- Twelve-key keyboard on front panel; 1 LED and 2 7-segment LED displays
- Automatic data-retention after switching off
- Fast and easy programming
- All-equipment programming option by MIDI EXCLUSIVE message
- Fits in extra-flat 19-inch rack

Enhanced programmable MIDI THRU function

What is a preset? In the case of the Q4, a preset is composed of 21 parameters, as shown in Table 1. The parameters can be classified in 5 groups of 4, and 1 linking parameter. The parameters are used in 3 mutually independent types of operation, whose function is briefly gone into below.

The first type of operation is the routeing of MIDI data received on channel 1. The Q4 enables immediate rerouteing of these data to 1, 2, 3 or 4 other MIDI



SEE APRIL 1989 P 30 FOR CORRECTION

Fig. 1. MIDI configuration example set up around control unit Q4 and a keyboard sending on channel 1. The Q4 controls 4 other MIDI instruments.

channels. This feature is of particular interest for users wishing to control more than one MIDI instrument from a single keyboard, which sends data via channel 1 to the Q4. This, in turn, arranges a distribution between, for example, channels 3, 7, 8 and 12. A change of preset from the MIDI master keyboard is sufficient to enable the Q4 to reroute received data on channel 1 to, for instance, channels 4 and 13; yet another preset may be called up instantaneously to effect rerouteing of channel 1 to, for example, 3, 7, 13 and 15. As already noted, presets may be selected on the master MIDI keyboard, or direct on the Q4's keyboard (note that a keyboard is of the MIDI master type when it has provisions for sending preset changing commands).

Parameters

The first four parameters, numbered P1 through P4, select the channels which are used for rerouteing of data received via channel 1. Data received on channels other than number 1 is normally processed within these channels, without modification.

If, for example, P1=12 and P2=15, all MIDI data received on channel 1 is sent to channels 12 and 15 also.

The currently used standards for MIDI specify that the value of this parameter is between 1 and 16. Value 0 indicates that no data is rerouted from channel 1 to any other channel; if all 4 rerouteing parameters are 0, information received via channel 1 is not rerouted. It will be clear that the first type of operation is best qualified as a *programmable MIDI THRU function*.

The second type of operation entails the programming of instruments that 'listen on' the various MIDI channels. Four strings of 4 parameters are available for assigning to 4 different MIDI channels. These strings are sent out once, following the calling up of the preset.

Channel select

The first parameter in each of the 4 strings, i.e., P5, P9, P13 and P17, defines the number of the MIDI channel to which the subsequent parameters in the string are sent (BANK SELECT, VOICE SELECT and SET VOLUME). Permissible values are 1 to 16. Value 0 is ignored. If, for instance, parameter P13 is assigned value 12, this should be taken to mean that the subsequent three parameters are intented for the instrument 'listening on' channel 12.

Bank select

In each of the 4 strings, the second parameters (P6, P10, P14 and P18) define the number of a sound selected on a synthesizer or expander on the MIDI channel indicated by the preceding parameter (P5, P9, P13 or P17). The bank select parameter is useful for instruments whose available sounds are stored in banks, either of the modifiable type (RAM), and of the non-modifiable type (ROM/EPROM).

Permissible values are 0 to 31. Value 99 indicates the absence of a BANK SELECT command, and is useful for equipment that does not have banks, such as the TX7 module from Yamaha. Value 11, for example, assigned to parameter P18, causes the instrument on the channel indicated by P17 to activate bank 11, from which the actual sound is selected by the value of the next parameter, P19 (VOICE SELECT — see below).

Voice select

Parameters P7, P11, P15 and P19 each define the number of the selected sound in the bank defined by the preceding parameter (P6, P10, P14 and P18) in the string sent to a synthesizer or expander. This procedure corresponds to a MIDI command known as PROGRAM CHANGE.

Permissible values are 1 to 99. Value 0 indicates the absence of a VOICE SELECT command. Value 98, for example, assigned to parameter P19, selects instrument sound 98 from the bank pointed to by P18, on the MIDI channel pointed to by P17.

Table 1.

	Function	Range	off	init
P1	MIDI channel routeing	[1 to 16]	00	01
P2	MIDI channel routeing	[1 to 16]	00	01
P3	MIDI channel routeing	[1 to 16]	00	01
P4	MIDI channel routeing	[1 to 16]	00	01
P5	MIDI channel	[1 to 16]	00	01
P6	bank	[0 to 31]	99	99
P7	voice	[1 to 99]	00	00
P8	volume	[1 to 64]	00	00
P9	MIDI channel	[1 to 16]	00	01
P10	bank	[0 to 31]	99	99
P11	voice	[1 to 99]	00	00
P12	volume	[1 to 64]	00	00
P13	MIDI channel	[1 to 16]	00	01
P14	bank	[0 to 31]	99	99
P15	voice	[1 to 99]	00	00
P16	volume	[1 to 64]	00	00
P17	MIDI channel	[1 to 16]	00	01
P18	bank	[0 to 31]	99	99
P19	voice	[1 to 99]	00	00
P20	volume	[1 to 64]	00	00
P21	links	[1 to 99]	00	00

Volume select

In the command string sent to the synthesizer or expander, parameters P8, P12, P16 and P20 each define the volume of the instrument sound selected with the aid of the previously discussed parameters.

Permissible values are 0 to 64, corresponding to the desired MIDI volume value divided by two. Value 55, for example, corresponds to MIDI volume word 110. Value 00 indicates the absence of a VOLUME SELECT command.

As an example how a command string is built from the above parameters, the instrument on MIDI channel 3 is programmed to select voice 23 in bank 6 at volume 120, with the aid of the following parameters:

P17=3: channel select
P18=6: bank select
P19=23: sound select
P20=60: volume select

This concludes the discussion of the second type of operation supported by the Q4 control unit. At this point, it may be useful to briefly recapitulate what has been said above. There are 4 parameters that allow data received on channel 1 to be rerouted to 1, 2, 3 or 4 other channels. In addition, 4 strings of 4 parameters each enable selecting a sound register (BANK), sound (VOICE) and volume, on 4 different MIDI channels.

The third type of operation controls linking (chaining) of presets:

Links

The third type of parameter in a preset string allows the linking (often called *chaining* in MIDI terminology) of two or more presets. If the complexity of the configuration to be programmed exceeds the possibilities offered by one preset, the user may link two or more presets by arranging parameter P21 to precede the number of the preset to be linked to the current preset. Permissible values are 1 to 99. Value 0 indicates that linking is not used.

If, for example, preset 4 is closed off with P21=73, preset 73 will be linked to preset 4.

Presets and the Q4's keyboard

Preset selection from the MIDI keyboard on the Q4 can only be effected when the keyboard used is capable of providing command MIDI PROGRAM SELECT with a parameter range of 0 to 99. Most MIDI master keyboards satisfy this condition at least partially. In any case, presets can be called up direct with the aid of the front panel controls of the Q4. Functionally, the keyboard looks like this:

0	2	3	4	5	6	7	8	9	P	E

In standard mode, these 12 keys allow direct selection of the desired preset number; in programming mode, they allow programming the presets.

Key P is used for entering and leaving the programming mode. An integral LED lights continuously when programming mode is selected, and briefly on reception of a MIDI string. In programming mode, key E steps to the next parameter (stepping back is not possible).

The Q4 displays][after power-up to show that it is ready after initializing. Initialization as described below is required once after building, and also if all parameters are to be cleared. Proceed as follows:

1. interrupt the Q4's power supply for at least 15 seconds;
2. hold key 0 pressed while applying power;
3. release key 0, and wait at least 15 seconds.

The display will show code t3 to indicate completion of the Q4's initialization. All other display indications at this stage point to faulty operation.

Avoid briefly interrupting the Q4's power supply, and allow for the delay of 15 seconds minimum after each interruption of the power, or the re-application of it. This precaution guarantees correct storage of data in the buffer memory.

Programming example

The following example shows how preset 36 is programmed such that data received on channel 1 is rerouted to channels 8 and 10. Preset 36 is also used to effect a change of sound on channel 8, and a another on channel 11. The instrument 'listening on' channel 8 is to actuate sound 88 from bank 3, at volume setting 102, while the instrument on channel 11 is to actuate sound 27 (no bank specified), at volume setting 68.

The first thing to do is complete a programming sheet as shown overleaf.

Key	Display	Explanation
P	[]	LED lights and programming may commence
36	36→01→xx	Number of preset is automatically followed by P1 and its value
08 E	08→02→xx	New value of P1 is 08 (reroute Ch. 1 to Ch. 8); next parameter (P2) appears automatically, followed by its current value (xx=00 after a reset)
10 E	10→03→xx	New value of P2 is 10 (reroute Ch. 1 to Ch. 10); next parameter (P3) appears automatically, followed by its current value (xx=00 after a reset)
00 E	00→04→xx	New value of P3 is 00 (not used); next parameter (P4) appears automatically, followed by its current value (xx=00 after a reset)
00 E	00→05→xx	New value of P4 is 00; next parameter (P5) appears automatically, followed by its current value (xx=00 after a reset)
08 E	08→06→xx	New value of P5 is 08 (programming string for Ch. 8); next parameter (P6) appears automatically, followed by its current value (xx=99 after a reset)
03 E	03→07→xx	New value of P6 is 03 (bank select 3 on Ch. 8); next parameter (P7) appears automatically, followed by its current value (xx=00 after a reset)
88 E	88→08→xx	New value of P7 is 88 (voice select 88 in bank 3 on Ch. 8); next parameter (P8) appears automatically, followed by its current value (xx=00 after a reset)
51 E	51→09→xx	New value of P8 is 51 (volume select 102 for sound 88 in bank 3 on Ch. 8); next parameter (P9) appears automatically, followed by its current value (xx=00 after a reset)
11 E	11→10→xx	New value of P9 is 11 (programming string for Ch. 11); current value of P10 is displayed
99 E	99→11→xx	New value of P10 is 99 (no bank select); current value of P11 is displayed
27 E	27→12→xx	New value of P11 is 27 (voice select 27); current value of P12 is displayed
34 E	34→13→xx	New value of P12 is 34 (volume select 68); current value of P13 is displayed
P	[ ]	LED in key P remains on; to leave programming mode, press 0 to cancel modifications, or press 1 to save modifications
1	xx	LED in key P goes out; preset permanently modified, but not sent via MIDI interface; xx is number of preset selected before programming mode was entered

The memory contents can now be examined:

Key	Display	Explanation
P	[ ]	Red LED lights
36	36→01→xx	Read value of P1 in preset 36 (xx=08 after above programming sequence)
E	02→xx	Read value of P2 (xx=10 after above programming sequence)
E	03→xx	Read value of P3 etc.

To end the memory read procedure, simply press key P, then 0. The LED in key P goes out.

Note: the software does not check whether the values assigned to the various parameters are in the permissible range.

Thanks to MIDI function EXCLUSIVE

Programming sheet

PRESET No. 36	PROGRAMMING SHEET MIDI Q4				
P1 route 1	P5 channel	P9 channel	P13 channel	P17 channel	E
8	8	11	0	0	L
P2 route 2	P6 bank	P10 bank	P14 bank	P18 bank	E K
1Ø	3	99	99	99	T
P3 route 3	P7 voice	P11 voice	P15 voice	P19 voice	O
ØØ	88	27	00	00	R
P4 route 4	P8 volume	P12 volume	P16 volume	P20 volume	P21 links
ØØ	51	34	00	00	0

Programming sheet

PRESET No. 7	PROGRAMMING SHEET MIDI Q4				
P1 route 1	P5 channel	P9 channel	P13 channel	P17 channel	E
1	1	4	6	12	L
P2 route 2	P6 bank	P10 bank	P14 bank	P18 bank	E K
2	99	5	0	3	T
P3 route 3	P7 voice	P11 voice	P15 voice	P19 voice	O
6	27	73	16	4	R
P4 route 4	P8 volume	P12 volume	P16 volume	P20 volume	P21 links
11	50	32	43	43	63

Programming sheet

PRESET No.	PROGRAMMING SHEET MIDI Q4				
P1 route 1	P5 channel	P9 channel	P13 channel	P17 channel	E
					L
P2 route 2	P6 bank	P10 bank	P14 bank	P18 bank	E K
					T
P3 route 3	P7 voice	P11 voice	P15 voice	P19 voice	O
					R
P4 route 4	P8 volume	P12 volume	P16 volume	P20 volume	P21 links

Programming sheet

PRESET No. 63	PROGRAMMING SHEET MIDI Q4				
P1 route 1	P5 channel	P9 channel	P13 channel	P17 channel	E
13	13	0	0	0	L
P2 route 2	P6 bank	P10 bank	P14 bank	P18 bank	E K
0	99	99	99	99	T
P3 route 3	P7 voice	P11 voice	P15 voice	P19 voice	O
0	ØØ	0	0	0	R
P4 route 4	P8 volume	P12 volume	P16 volume	P20 volume	P21 links
0	50	0	0	0	0

Make copies of this programming sheet and use it as shown in the examples.

MESSAGE, the Q4 can also be programmed from a computer. Experienced programmers may note the following structure of the exclusive message — from which can be deduced that the designer's name is Henri — for the Q4:

F0 48 45 4E 52 49 49 01 pp dd ... dd F7

Value pp is the preset to be read, dd a 32-byte string in which bytes 1 to 21 correspond to parameters of the wanted preset, and bytes 22 to 32 are zeroes.

Circuit description

The circuit description is kept short because most users of the Q4 will prefer practical guidance in using the unit over a detailed discussion of the operation of, say, the internal microcontroller. After all, the microcontroller is basically but a means to an end. None the less, some elementary information on it is provided.

The internal structure of the Type HD63B03XP microcontroller is given in Fig. 3. The chip is an 8-bit processor with a 192-byte on-board RAM, 24 I/O lines, a serial communication port, and two timers. The control program for the Q4 is not internal to the HD63B03XP, but is loaded in an external EPROM.

The practical circuit of the Q4 is given in Fig. 2. The address and data buses are not multiplexed, and peripheral hardware is controlled via 24 lines. The microcontroller is housed in a 64-pin DIL enclosure. External RAM IC_3 is powered by a 3-cell NiCd battery, and so ensures the data back-up function. Watchdog IC_5 prevents power interruptions causing garbled data in IC_3, and also arranges the correct power-on timing of the microcontroller.

Resistor R_{13} may be redimensioned to ensure optimum loading of the NiCd battery used — the indicated value results in a charge current between 300 and 400 μA (the current drawn by the RAM is about 10 times smaller). If the Q4 is not used frequently, it is recommended to lower the value of R_{13} to 100 Ω. The maximum charge is about 11 mA during 14 hours.

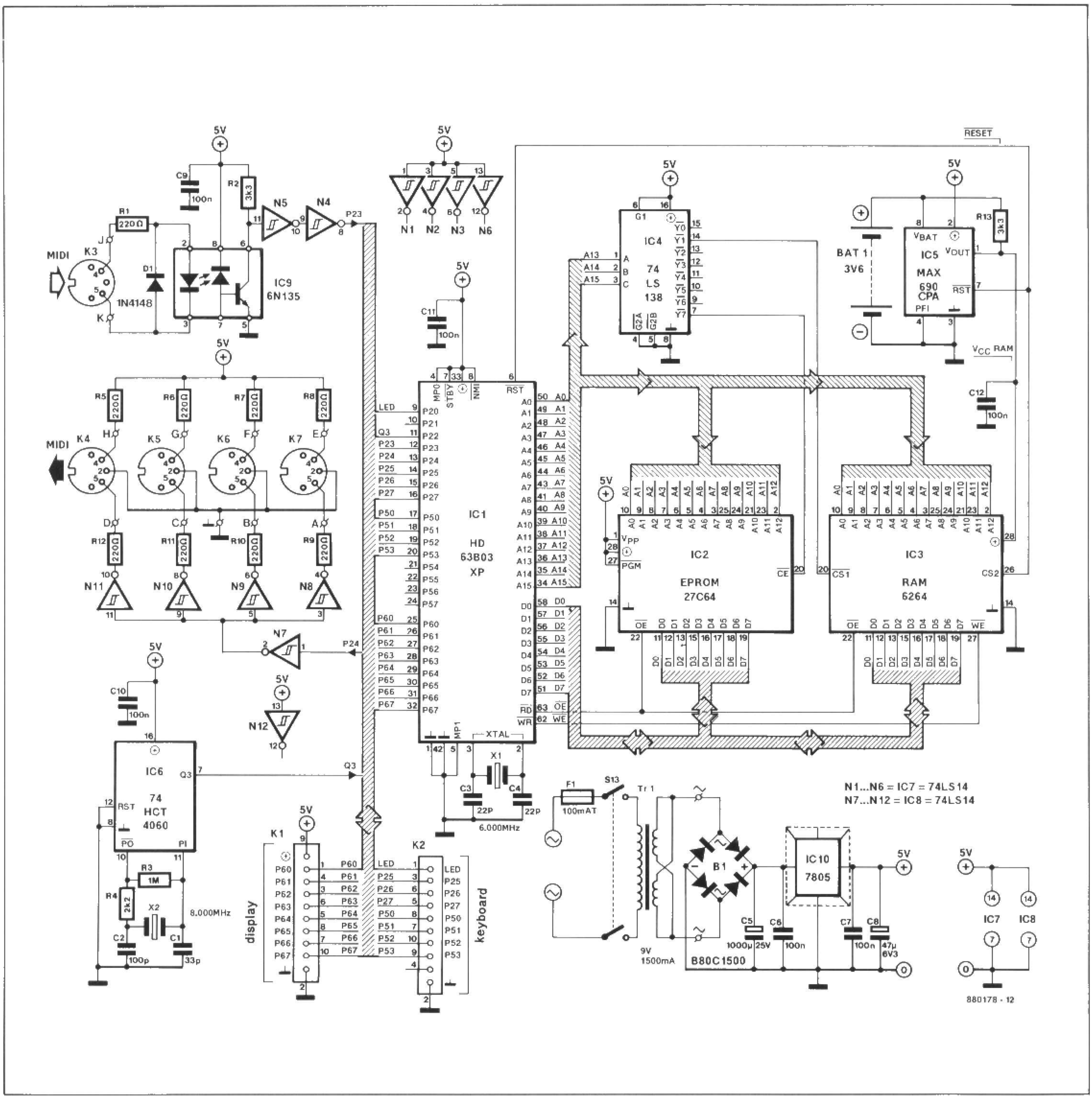


Fig. 2. Circuit diagram of the main controller circuit in the Q4.

The keyboard and the displays are mounted on a separate board (Fig. 4). The microcontroller drives the LED inside key P via buffer T_1. Inverting buffers are provided between the MIDI input/outputs and the associated peripheral control lines of the microcontroller. Note that the MIDI standard is based on serial communcation with the aid of a current-loop that guarantees electrical insulation between connected devices, whence the optocoupler at the MIDI input of the Q4. Only pins 2 of the DIN-type output connectors are connected to the circuit ground. The four MIDI outputs provided are identical and fully interchangeable (remember that instrument selection is a matter of software, not of connectors and/or cables). More MIDI outputs can be provided on the Q4 by using additional DIN sockets and spare TTL buffers/inverters N_1, N_2, N_3, N_6 and N_{12}. A MIDI THRU output can be created by tapping the signal between N_5 and N_4, and feeding it to a spare TTL buffer/inverter.
The 500 kHz MIDI clock signal in the Q4 is provided by oscillator/divider IC_6, a Type 4060.

The display/keyboard circuit is shown in Fig. 4. The two common-anode 7-segment LED displays are driven by BCD-to-7-segment decoders Type 74LS247. The 12 keys used for programming the Q4 are scanned by the microcontroller, and their state is processed in software.

Construction

Although the construction of the MIDI control unit Q4 is greatly simplified by the availablity of a ready-made, single-sided printed circuit board (Fig. 5), inexperienced constructors are well advised to read the following carefully. Musicians interested in building the Q4, but unsure of their soldering skills, may have to rely on a friend with experience in practical electronics.

There are no through tracks in between pins of the microprocessor socket because this has a lead spacing smaller than the standard 2.54 mm (0.1 in). This fact has given rise to a relatively high number of wire links on the main board: there are 24 wires in all.
Note the orientation of voltage regulator IC_{10}, whose metal tab is turned towards the other components.
All integrated circuits on the main board must be fitted in good-quality sockets (note the orientation!). Some ICs these days do not have a notch to aid in orientation, but a lenghtwise asymetrically located groove. If the IC is viewed from the top side, pin 1 is located at the extreme left in the lower row of pins when the groove is horizontal and nearest to you.

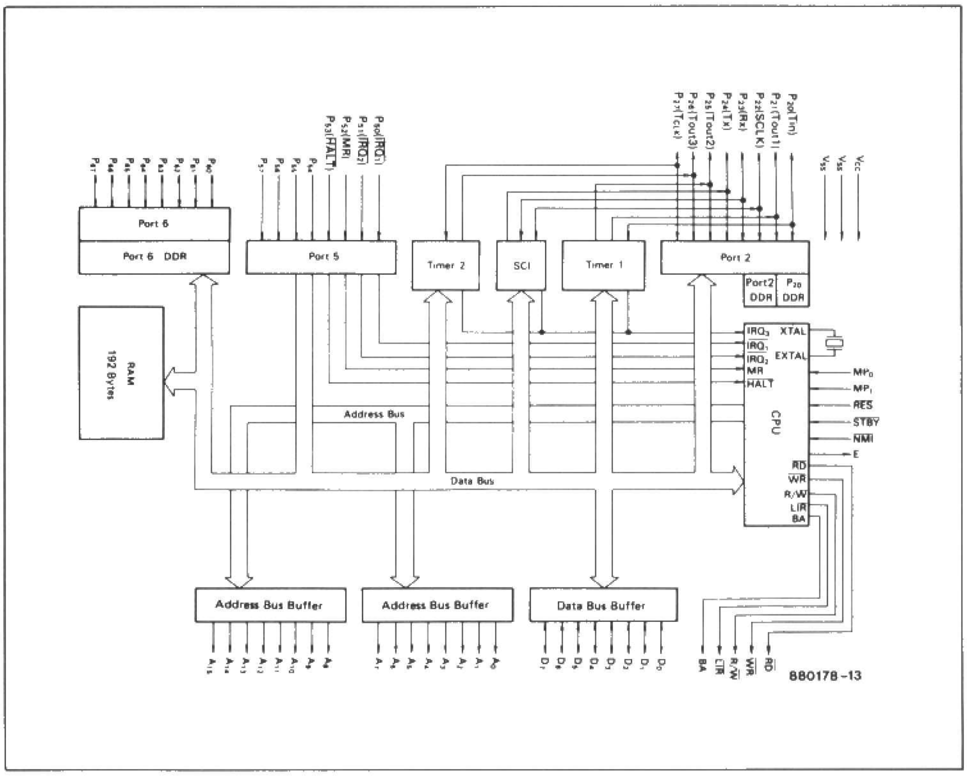


Fig. 3. HD63B03X architecture. Note that lines P23 and P24 are used here to send and receive serial MIDI data.

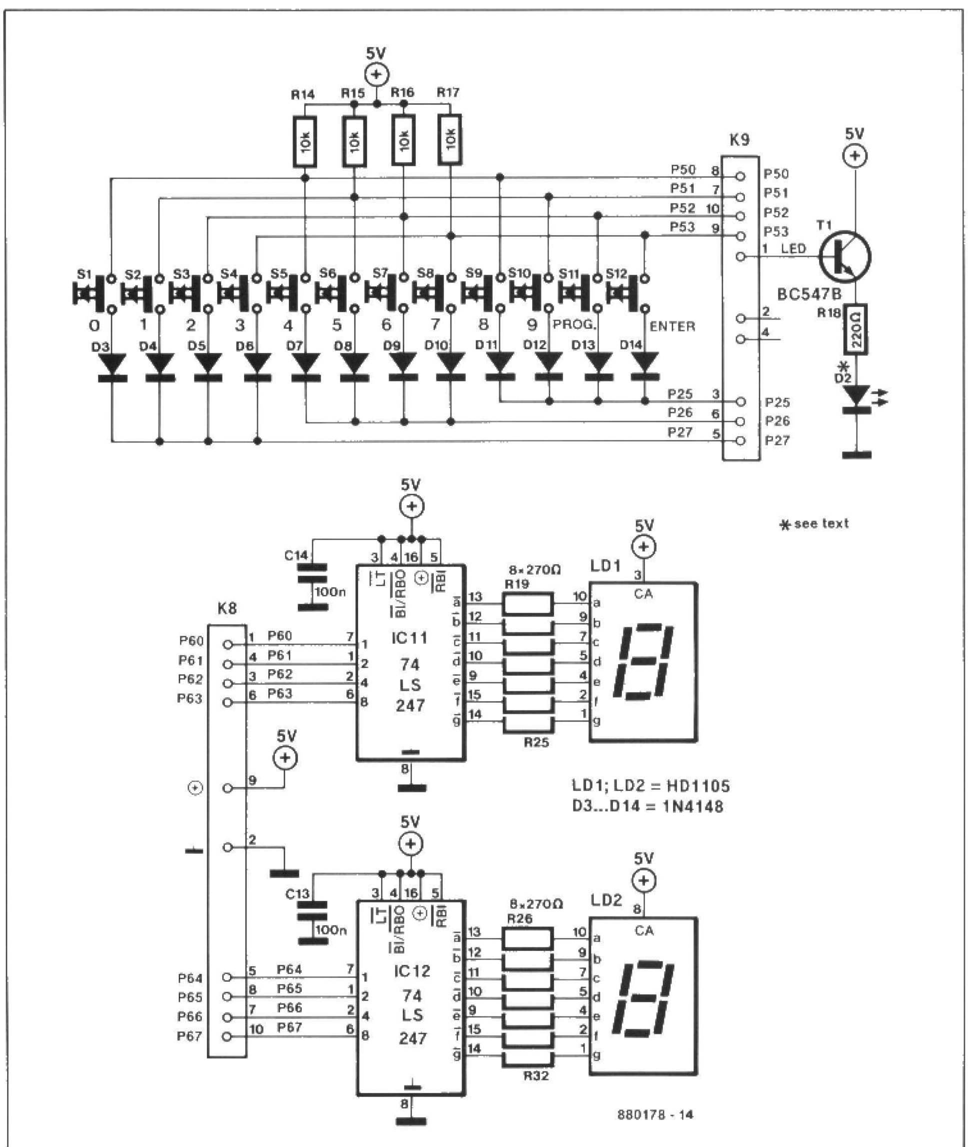


Fig. 4. Circuit diagram of the keyboard/display unit, which is built on a separate board.

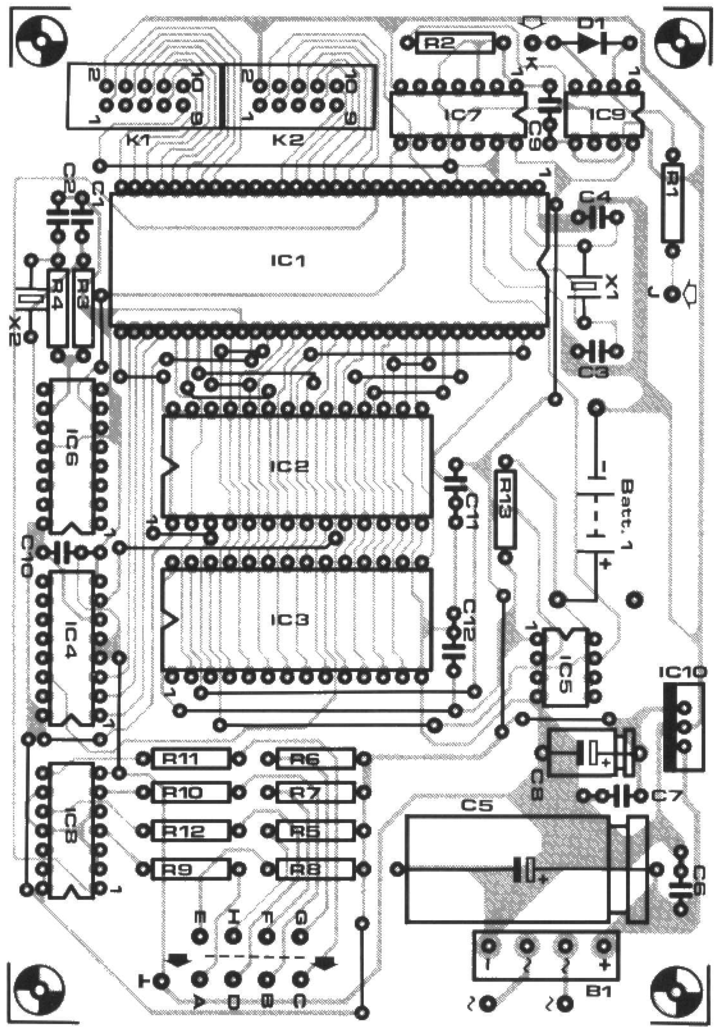


Fig. 5. Component mounting plan of the main controller board in the Q4.

Parts list

MAIN BOARD

Resistors (±5%):
R_1;R_5 to R_{12} incl. = 220R
R_2;R_{13} = 3K3
R_3 = 1M0
R_4 = 2K2

Capacitors:
C_1 = 33p
C_2 = 100p
C_3;C_4 = 22p
C_5 = 1000μ; 25 V
C_6;C_7;C_9 to C_{12} incl. = 100n
C_8 = 47μ; 6V3

Semiconductors:
IC_1 = HD63B03XP (Hitachi)
IC_2 = 2764 (*Elektor Electronics* order number ESS570; see Readers Services page).
IC_3 = 6264 or MB8264-15L
IC_4 = 74LS138
IC_5 = MAX690 (Maxim Integrated Products Inc.)
IC_6 = 74HCT4060
IC_7;IC_8 = 74LS14
IC_9 = 6N135 or 6N136
IC_{10} = 7805

Miscellaneous:
X_1 = quartz crystal 6 MHz.
X_2 = quartz crystal 8 MHz.
Batt.1 = NiCd 3V6 battery (e.g. Maplin order no. RK46A)
K_1;K_2 = 10 way PCB pin header.
K_3;K_4;K_5;K_6;K_7 = 5-way DIN socket.
Tr_1 = 9 V; 500 mA mains transformer; preferably toroidal.
11 off solder terminals.
PCB Type 880178-1 (see Readers Services page).

Parts not on PCB:
F_1 = 100 mA delayed action fuse with panel-mount holder.
S_{13} = double-pole mains switch.
Euro-style mains entrance socket with integral filter.
2 off 10-way flat ribbon cables (approx. length: 30 cm)
4 off female 10-way IDC connectors.

To facilitate mounting the completed display/keyboard unit on to the front panel of the enclosure, it is recommended not to use sockets for the ICs or the displays. The keys, S_1 to S_{12}, are Digitast (ITT/Schadow) push-to-make types. S_{11} has a red keytop and a hole for mounting LED D_2.
The main board is connected to the display board via 2 short lengths of flat-ribbon cable terminated in male 10-way IDC headers that mate with K_1 and K_2 (main board) and K_8 and K_9 (fitted at the track side of the display board). There are 10 wire links on the display board. Four are located at the track side: one below S_5, one between S_5 and S_6, and one below S_9.
Pay attention to the orientation of the diodes on penalty of getting stuck with a difficult-to-find hardware bug.

Table 5.

Q4 status codes

Code	Problem	Remedy
t1	cannot handle amount of MIDI data received	turn power off and on again
t2	one or more errors in back-up memory	initialize or a. go into programming mode b. quit (0) c. verify all presets
t3	initialization completed after required reset	---
t4	will not handle command PROGRAM CHANGE with value over 99; replaced with unchanged PROGRAM CHANGE command	---

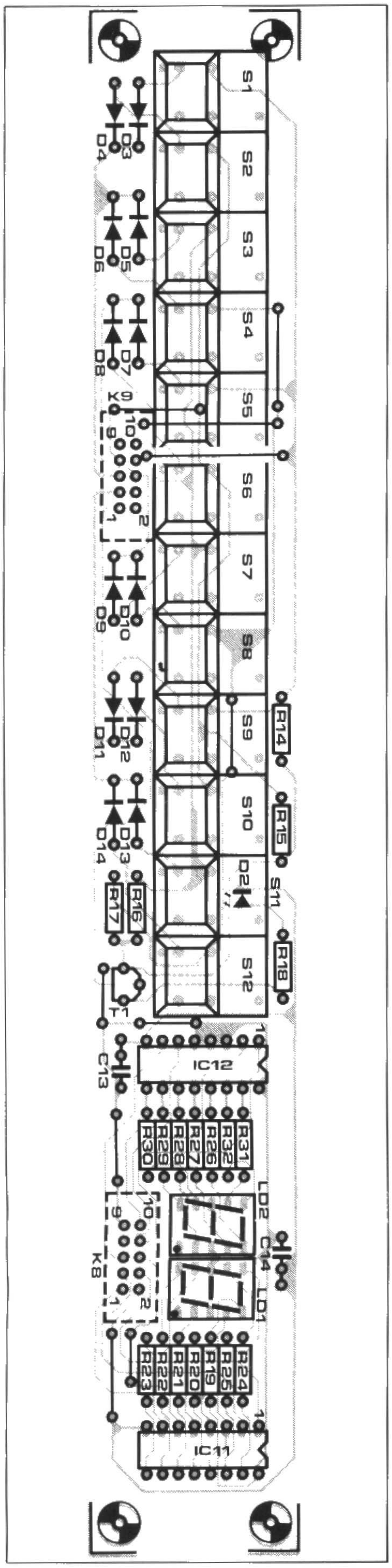
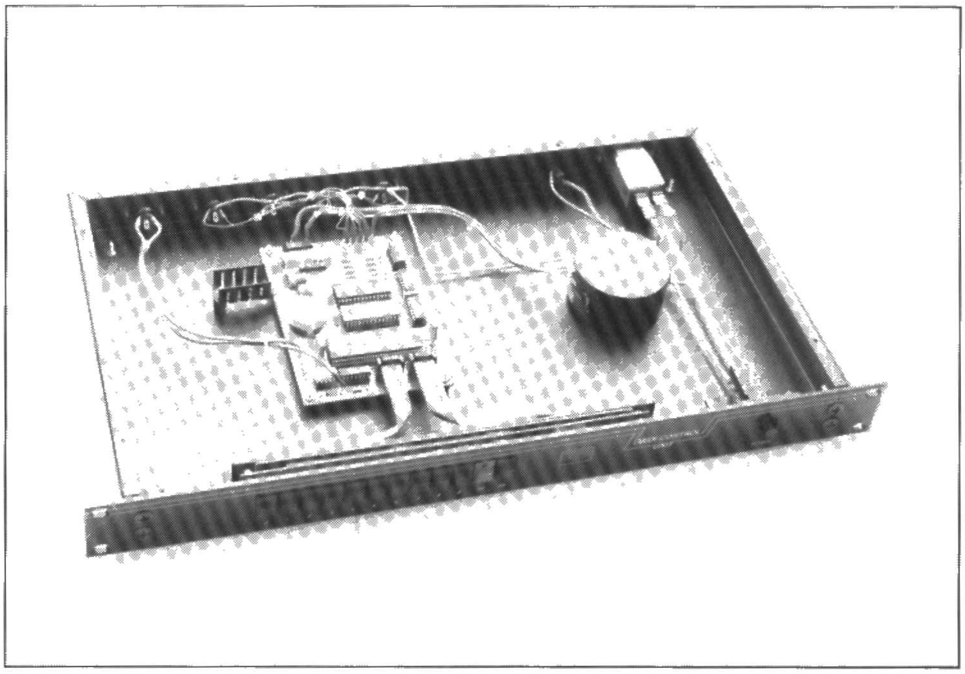
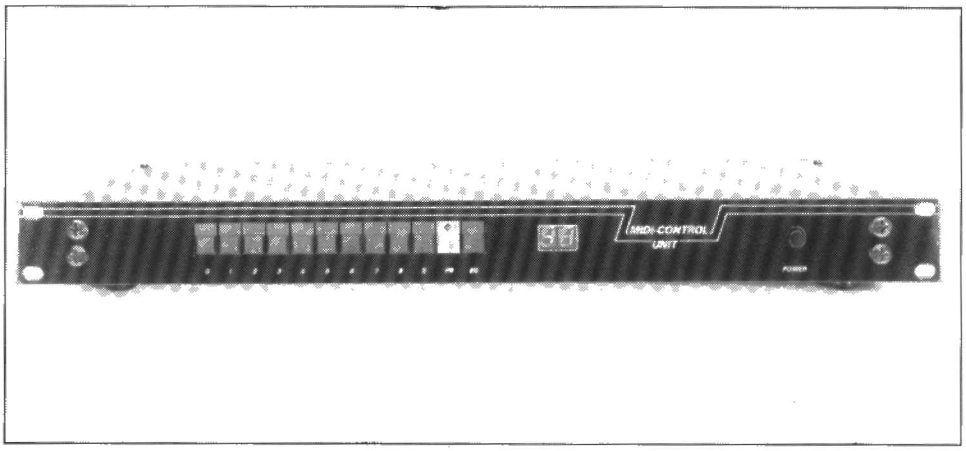


Fig. 6. Printed circuit board for the front-panel mounted display/keyboard unit. To prevent damage when the keys are being pressed, it is recommended to provide some form of support between the centre of the completed board and the inside of the front panel.





Parts list

DISPLAY/KEYBOARD

Resistors (±5%):
R14;R15;R16;R17 = 10K
R18 = 220R
R19 to R32 incl. = 270R

Capacitors:
C13;C14 = 100n

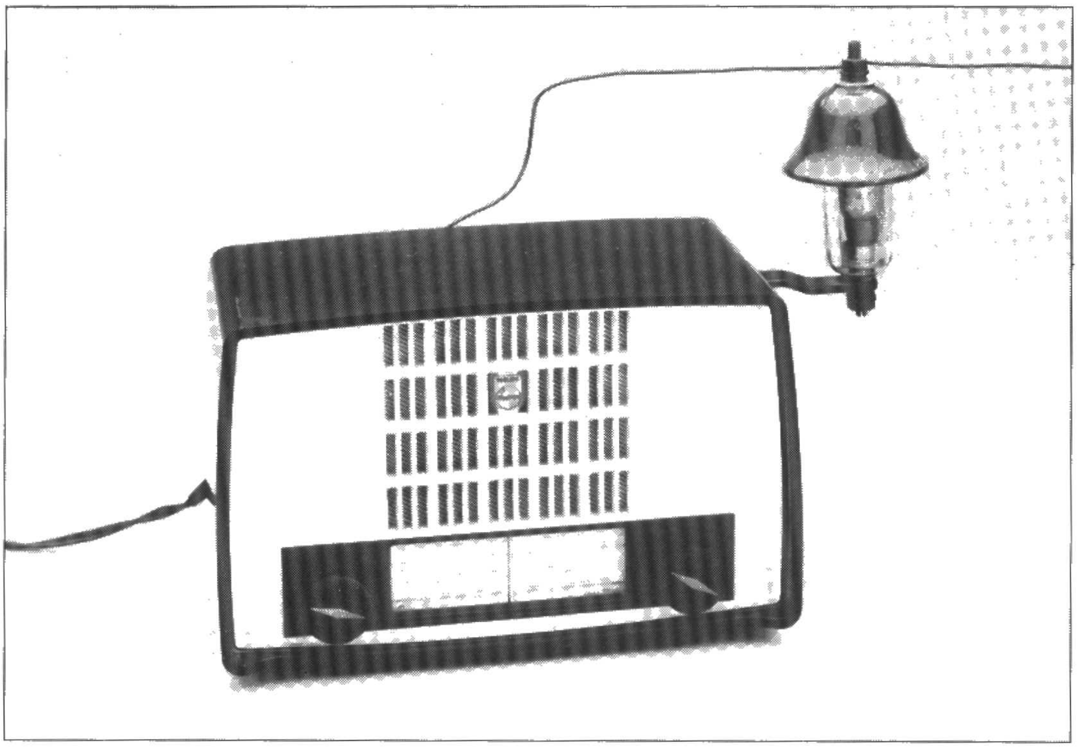
Semiconductors:
D1;D3 to D14 incl. = 1N4148
D2 = red LED
B1 = B80C1500 rectangular bridge rectifier
LD1;LD2 = HD1105 (Siemens; common anode; listed by ElectroValue Ltd.)
T1 = BC547B
IC11;IC12 = 74LS247

Miscellaneous:
S1 to S12 incl. = Digitast key.
K8;K9 = 10 way PCB pin header.
PCB type 880178-2 (see Readers Services page).

On the MIDI input socket, be sure that solder terminal J is wired to pin 4 of the DIN socket, and terminal K to pin 5. The same goes for output terminals E, F, G and H (pins 4) and A, B, C and D (pins 5). Light-duty, unshielded wire may be used between the DIN sockets and the board, provided the distance does not exceed 15 cm or so.

Do not fit the integrated circuits into their respective sockets before the presence of the supply voltage has been ascertained on all relevant pins. Great care and precision should be excercised in the fitting of the 64-pin microcontroller into its socket (ONCE AGAIN verify the orientation!).
Finally, it is recommended to use a mains filter ahead of the power transformer in the Q4.

OVER-VOLTAGE PROTECTION



The use of some form of over-voltage protection in electronic equipment is often not contemplated until a huge voltage surge has caused considerable damage. Since it is invariably better to be safe than sorry, this article looks at two over-voltage protection devices (*surge arresters*), the varistor and the gas-filled conductor, and discusses their operation and application.

Over-voltage is basically any voltage that exceeds the nominal value plus the stated tolerance. Over-voltage can be generated by various sources, of which lightning is probably the best known. A thunderstorm, even while it is several miles away, can give rise to voltage peaks of considerable amplitude on the mains network. The switching on and off of relatively heavy loads connected to long wires or conductors, which form a considerable self-inductance, also causes such peaks. The mains network is, however, not the only large self-inductance where over-voltage protection is required: model railway systems, telephone and computer networks are also prone to picking up interference and surges with a disastrous effect.

A number of components are available for over-voltage protection. In electronic circuits, much use is made of conventional diodes, suppressor diodes and zener diodes. The varistor is an interesting component that has already been used in a number of projects recently featured in *Elektor Electronics*.

Figure 1 shows a comparison between the 4 most commonly used types of over-voltage protection device, in respect of

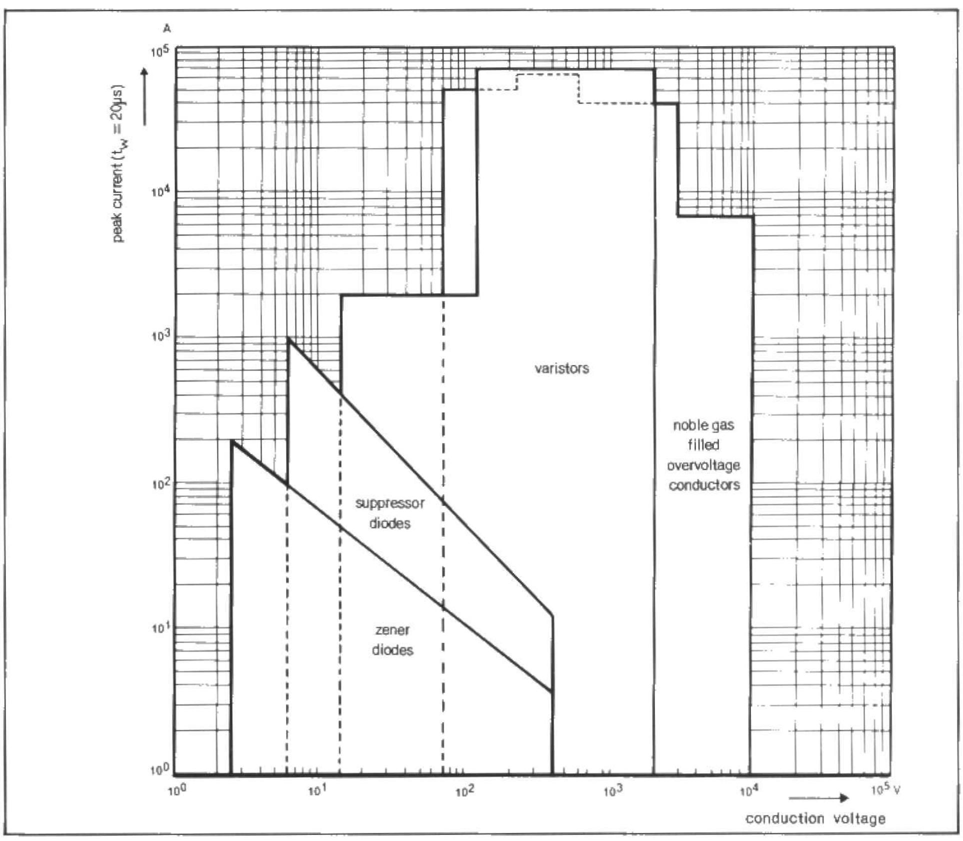


Fig. 1. This chart shows maximum peak current ($t = 20\ \mu s$) as a function of conduction voltage for four types of over-voltage protection device.

0.1 mA when the varistor does not conduct. In the rounded part at the low side of the curve, the internal resistance is mainly determined by R_V, which is much smaller than R_Z, but still larger than R_B. At large currents, the resistance of the ideal varistor is practically nought. The ohmic resistance of the metal-oxide parts (R_B) then determines the internal resistance. Capacitor C is relatively large (100 to 4000 pF). Without additional components, such as series-connected variable capacitance diodes, varistors are, therefore, unsuitable for high-frequency applications. Related to over-voltage protection, however, the internal capacitance is useful because it provides some smoothing of voltage surges. Inductor L represents mainly the self-inductance of the varistor's wires. For optimum speed of the varistor, these wires should be kept as short as possible.

At less common nominal voltages, a suitable varistor may be made from series-connected varistors individiually specified for a lower nominal voltage. When this is done, care should be taken to use varistors from the same series. Parallel connection of varistors is not possible owing to tolerance on the effective surface area. In the worst case, this tolerance may cause currents in parallel-conected varistors to differ by as much as a factor 1,000. Selecting matched types is particularly difficult for high peak currents, since measuring and generating these require specialized equipment.

The electrical behaviour of a varistor in overload conditions depends on the type of overload. A too high peak current causes the varistor to explode, so that the connection is broken. A long-term, light, overload gives rise to mixing of the metal-oxide granules, so that the varistor changes gradually into a low-value resistor.

Evidently, there exist no maximum values for voltage and current surges, so that a correctly selected varistor may still be overloaded. With this in mind, it is clear why varistors are typically mounted at some distance from other components, especially when used for suppression of interference on low-impedance networks, such as the mains.

Which varistor?

In general, the choice of varistor for a particular application is made on the basis of the datasheets supplied by the manufacturer. First, the operating voltage is determined, taking care not to confuse the DC and AC specifications. Next, the tolerance is added to the nominal voltage, and the result is rounded off to the next higher value in the series. For most applications with 240 V and 220 V mains networks, a 250 V varistor is adequate. Maximum peak current and energy absorbtion are then determined, and a suitable type is selected. The U-I characteristic of the varistor shows the maximum voltage across the varistor when this conducts. If this voltage is higher than the maximum permissible voltage for the protected circuit, a different varistor with a more appropriate U-I charcteristic will have to be found.

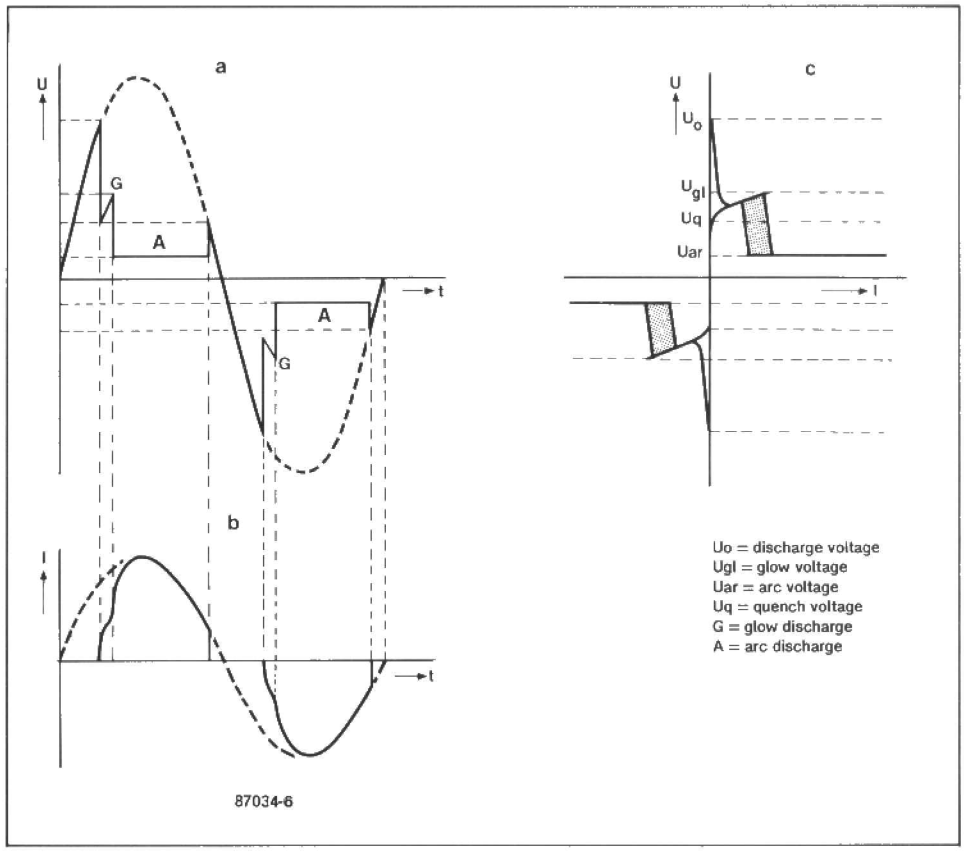


Fig. 6. Current/voltage response of a noble-gas filled surge arrester to a sinusoidal voltage.

Noble-gas filled surge arresters

This type of over-voltage protection device is based on the gas discharge principle, as illustrated in Fig. 6. Once the sinusoidal voltage has reached the discharge level, U_d, a glow discharge takes place that brings the voltage down to 70 to 150 V. Current is then 0.1 A to 1.5 A. If the current rises, an arc discharge takes place that brings the voltage down

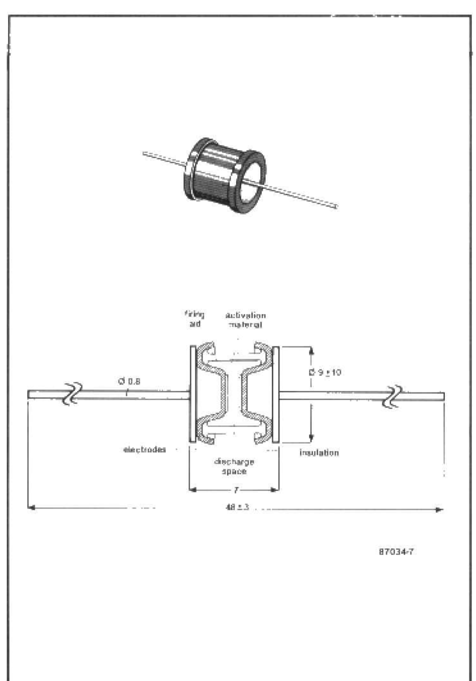


Fig. 7. Internal structure of a noble-gas filled surge arrester.

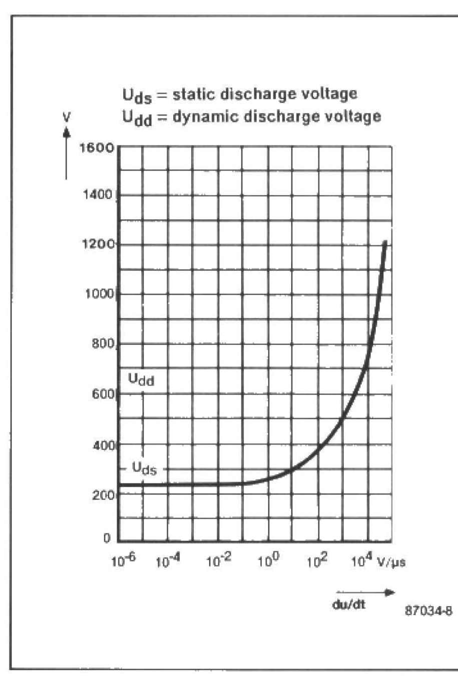


Fig. 8. Conduction voltage, V, of a noble-gas filled surge arrester as a function of the rate of rise, du/dt, of the over-voltage pulse.

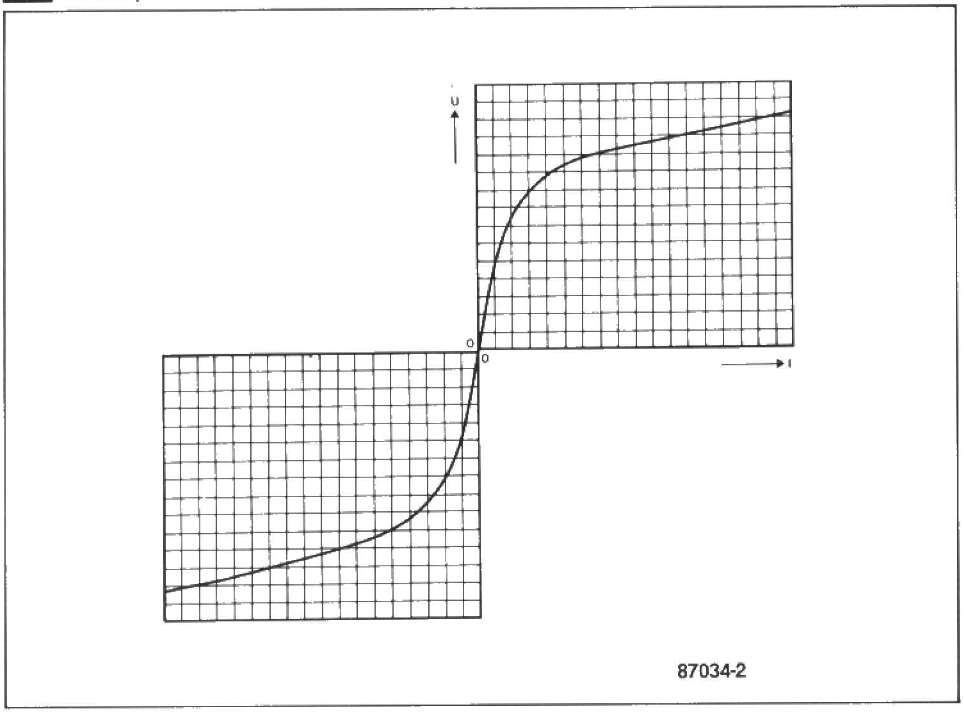


Fig. 2. Symmetrical U-I characteristic of a varistor.

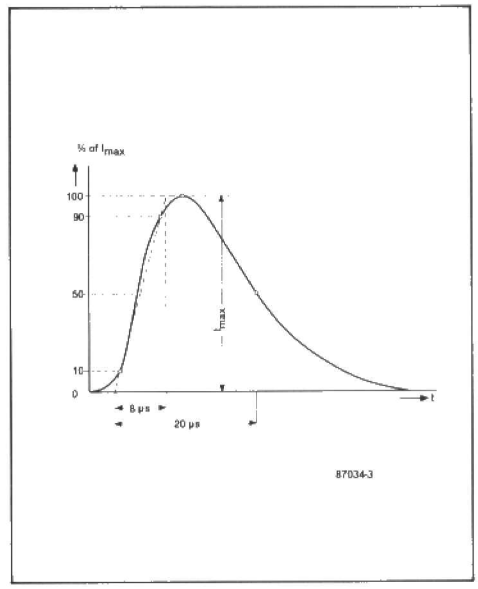


Fig. 3. Shape definition of the so-called 8/20 surge used for measuring the maximum peak current capability of over-voltage protection devices. The repeat rate of this pulse is 30 seconds or 3 minutes, depending on the test method adopted.

conduction voltage and maximum peak current during conduction. This article mainly focuses on varistors and gas-filled surge arresters.

Conducting ceramics

The varistor, also called VDR (voltage-dependent resistor), is comparable, to some extent, to the zener diode. The difference is mainly that the U-I characteristic of the varistor is symmetrical, i.e., the zener effect occurs with positive as well as negative current. The curve in Fig. 2 is obtained from

$I = KU^{\alpha}$

or

$U = CI^{\beta}$

where
I = current through varistor
U = voltage across varistor
K; C = a constant dependent on size of varistor element; $K = 1/C^{\alpha}$
α; β = material constants; $\alpha = 1/\beta$.

Both constants, α and K (or β and C), are taken from the manufacturer's data sheets. Depending on the application range, additional data is provided. Among these is the maximum peak current, I_{max}. The graph in Fig. 3 shows a so-called 8/20 μs current surge, which is used by a number of manufacturers for specifying the electrical characteristics of their varistors. Even for small varistors, the value of I_{max} is expressed in kilo-amperes (kA).

The disc-shaped ceramic element in a varistor is typically made from a metal-oxide powder — usually zinc-oxide (ZnO), titanium-oxide (TiO) or silicon-carbide (SiC). The simplified internal structure of the ceramic element is shown in Fig. 4. A micro-varistor is created where granules touch. The separation layer forms a high resistance, causing current to flow through the oxide granules and the micro-varistors. This fact makes it possible to set up a few rules of thumb for the design and use of varistors. Doubling the thickness of the ceramic plate will result in a doubled breakdown voltage, since the number of micro-varistors in series is then doubled. Similary, doubling of the surface area results in a higher maximum peak current since the number of current paths arranged in parallel is doubled. Lastly, doubling the volume results in double the amount of energy that can be absorbed.

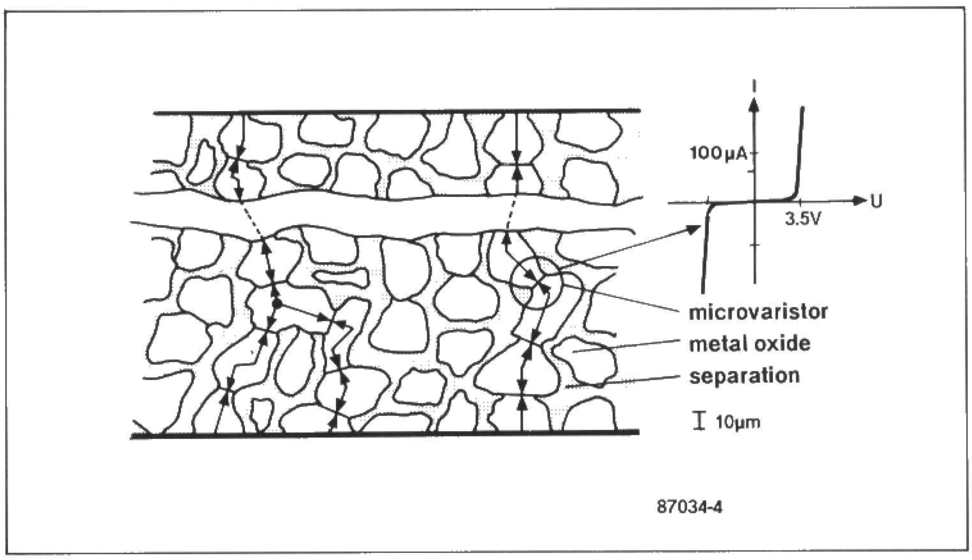


Fig. 4. Basic structure of the ceramic material used in a varistor.

The equivalent circuit of a varistor is drawn in Fig. 5. R_V is an ideal varistor. R_Z causes a leakage current of less than

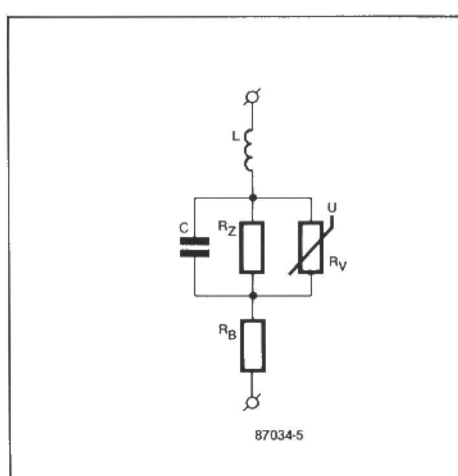


Fig. 5. Equivalent circuit of a varistor.

to 10 to 20 V. As the current becomes smaller, the arc will extinguish at 10 to 100 mA. After a short glow phase, the surge arrester reverts to its normal state. Combination of the voltage and current curves yields the U-I characteristic shown in Fig. 6c. It is seen that the voltage across the conductor decreases rapidly when ignition occurs. This is in contrast to the varistor, which maintains a largely constant voltage.

The internal structure of the noble-gas filled surge arrester is illustrated in Fig. 7. The device is hermetically sealed to prevent ambient parameters, such as gas type, gas pressure, relative humidity and pollution, from changing its carefully defined electrical characteristics. The electrodes are covered in a material that facilitates electron emission. A firing aid may be mounted at the inside of the insulator to speed up reaction time. The electrical characteristics of the noble-gas filled surge arrester are determined mainly by the type of gas, gas pressure, and electrode activation material.

Figure 8 shows that the discharge voltage rises if the rate of rise of the interferering voltage exceeds a certain value. As already seen in Fig. 6, the noble-gas filled surge arrester is not extinguished until the instantaneous voltage falls below the quench voltage, U_q. This is not a problem with alternating voltages, but direct voltages higher than the quench voltage may give rise to difficulties. Everything is fine as long as the the internal resistance of the voltage source is so high as to cause the voltage at the relevant current to drop below the quench voltage. A problem arises, however, if the internal resistance of the voltage source is so low that the surge arrester is not quenched. Fortunately, quenching can still be ensured by connecting a varistor in series with the gas-filled surge arrester as shown in Fig. 9. Since, after the interfering pulse has disappeared, the voltage across the varistor remains fairly constant, the voltage across the conductor is sure to fall below the quench level. Further applications of this series circuit arise where low capacitance (1 to 10 pF) as well as high resistance ($>10^{10}$ Ω) are required, but where voltage dips down to the arc level are just as harmful as over-voltage surges. Following the discharging of the gas-filled surge arrester, the varistor ensures that the voltage remains within safe limits (see Fig. 9b).

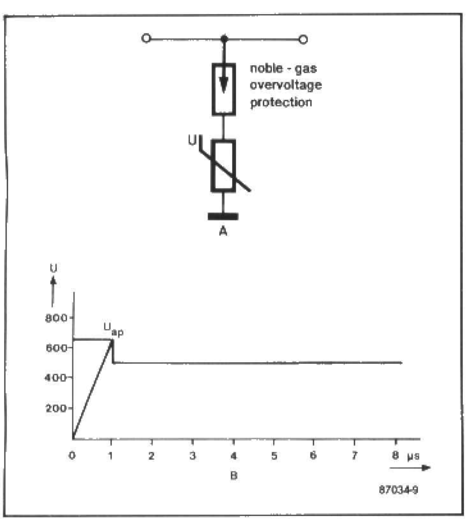


Fig. 9. Series connection of a noble-gas filled surge arrester and a metal-oxide varistor. The graph shows the voltage across the combination.

Over-voltage protection in practice

As an example of a practical application, Fig. 10 shows how a varistor can prevent over-voltage damaging, say, a computer. In practice, it will be found that fitting small varistors in all available equipment gives better results than a single, high-energy, varistor fitted at a central location across the mains lines. The varistor type given in Fig. 10 is conservatively rated because the degree and nature of the interference are hard to predict. In general, the choice of a suitable varistor is not critical in protection circuits for low-power equipment — in this case, the nominal voltage is the main criterium.

Provided there is room to fit them, varistors may also be used to prevent arcing on the collector of small DC motors — see Fig. 11. For AC as well as DC model railway systems, it is recommended to use varistors on motors and track sections.

Source:

Gas-filled over-voltage conductors, metal-oxide varistors (SIOV). Siemens Publication.

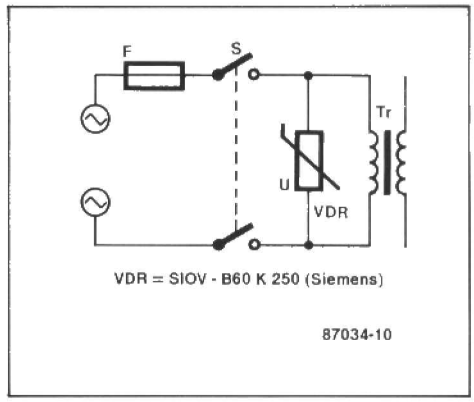


Fig. 10. Typical varistor application.

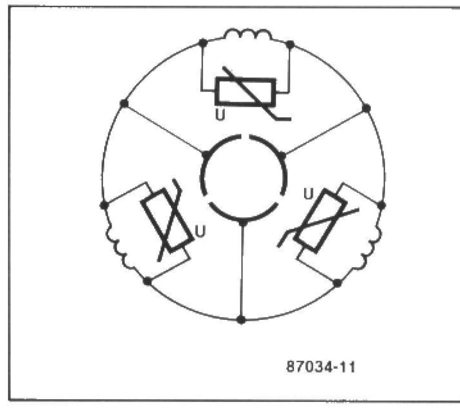
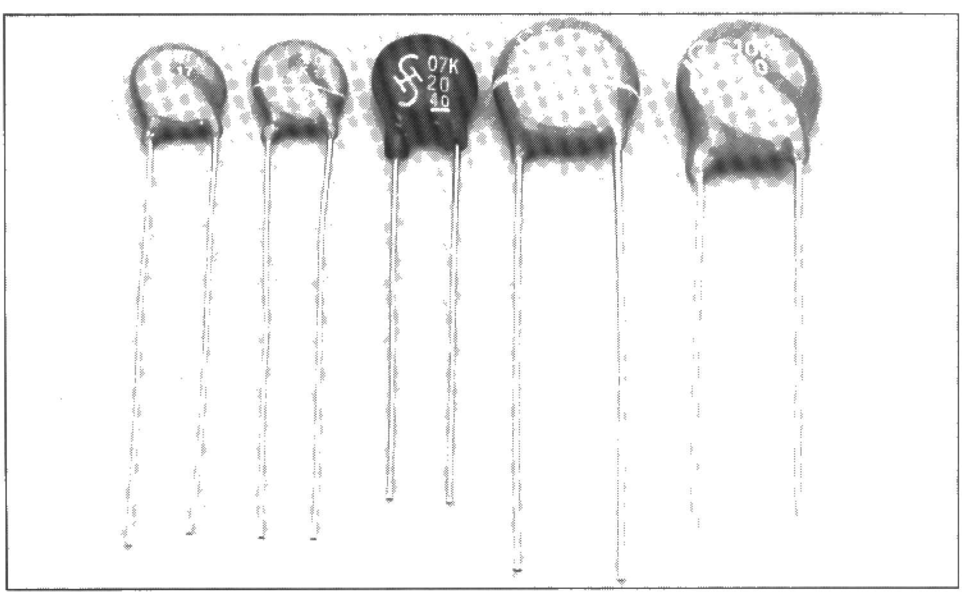


Fig. 11. Arcing at the collector of a DC motor can be prevented by fitting three varistors on the rotor.

Component availability note:

A range of Siemens SIOV varistors, including the Type S10K250 used in recent *Elektor Electronics* projects, is available from ElectroValue Limited • 28 St Judes Road • Englefield Green • Egham • Surrey TW20 0HB. Telephone: (0784) 33603. Telex: 264475. Fax: (0784) 35216. Northern branch: 680 Burnage Lane • Manchester M19 1NA. Telephone: (061 432) 4945.



On Siemens's range of varistors, S stands for disc-type (B = block type); the following two-digit number indicates the diameter of the varistor element; K indicates a tolerance of 10% (J = 5%; S = special); the last number indicates $U_{rms(max)}$. SIOV (SIemens metalOxide Varistor) is a registered trademark.

THYRISTOR SPEED CONTROL

This low-cost circuit gives excellent speed and torque control of series motors rated up to 3500 W as used in electric drills, saws and grinding machines. Built from only seven components, the speed controller is suitable for fitting into a compact ABS enclosure with mains input and output.

Electric tools with electronic speed control are invariably more expensive than tools without this useful facility. If the purchase of several tools is considered, it is, therefore, a good idea to decide on the construction of a single speed control unit that can be used with all electric tools, including the ones already available.

The thyristor speed control circuit is, of course, also suitable for loads other than electric tools. Intensity control of a normal bulb, for instance, is possible when it is remembered that the maximum output power of the circuit is only half the nominal power consumption of the load. This is so because the circuit uses only half periods of the sinusoidal input voltage. The insertion of a bridge rectifier, rated at 400 V/10 A, between the mains and the input of the speed control circuit, affords regulation over the full power range. For the application discussed here (speed control of series motors), however, the bridge rectifier should not be used.

The circuit diagram of the speed control unit is given in Fig. 1. Capacitor C_1 and inductor L_1 form a filter for suppression of interference on the mains, generated when the control circuit is triggered during the conduction phase. Since diodes D_1 and D_2 do not conduct during the negative half period of mains voltage, potential divider R_1-P_1 supplies only positive voltage to the gate (G) of thyristor Th_1. This means that the load is only powered during the positive excursions of the mains voltage — hence, the maximum power that can be supplied is half the nominal power consumption of the load, so that the maximum speed of the motor in the tool is reduced also. In most cases, this is not a problem since speed regulation is useful for relatively low speeds only. The power reduction even has an advantage in that it gives greater accuracy of speed control because the full range of the potentiometer is available for a relatively small speed range.

Circuit description

The speed control circuit is based on power regulation with the aid of a thyristor, Th_1, which conducts only at a user-defined phase angle of the positive half cycle of the alternating mains voltage. The difference between the gate potential of the thyristor and the reverse electromotive force (EMF) supplied by the motor determines when Th_1 is fired. Firing takes place when the gate is a few volts positive relative to the voltage across the motor.

The reverse EMF generated by the motor rises with the speed this runs at. This means that the thyristor will be fired less frequently as the motor runs free (i.e.,

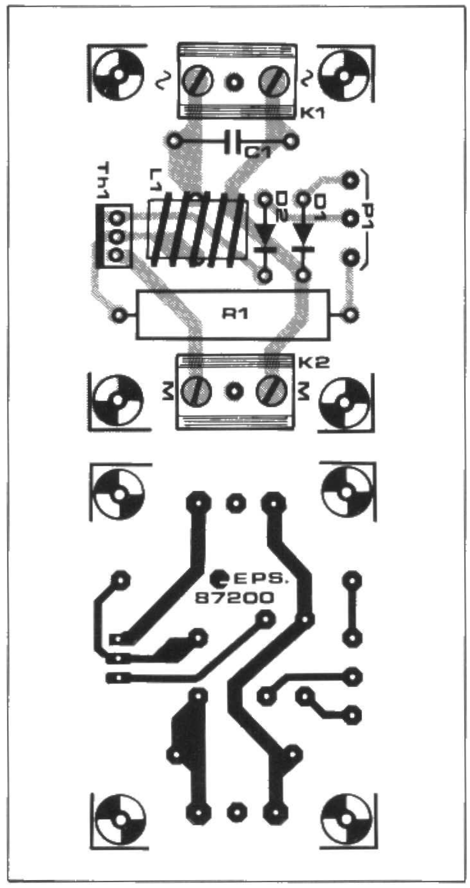


Fig. 2. Track layout and component overlay of the printed circuit board for the speed controller.

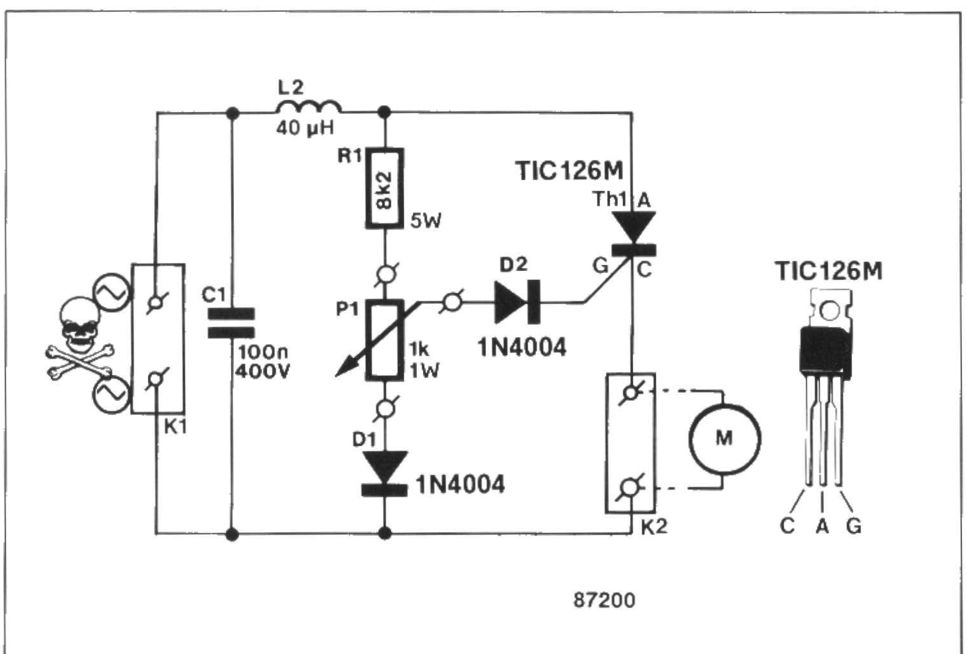


Fig. 1. Circuit diagram of the low-cost, thyristor-based, speed control circuit.

Parts list

Resistors:
R_1 = 8K2; 5 W
P_1 = 1K0; 1 W; wirewound potentiometer with plastic shaft

Capacitor:
C_1 = 100n; 400 VDC (250 VAC)

Semiconductors:
D_1;D_2 = 1N4004
Th_1 = TIC126M

Inductor:
L_1 = 40µH; 10 A suppressor choke (Omni Electronics).

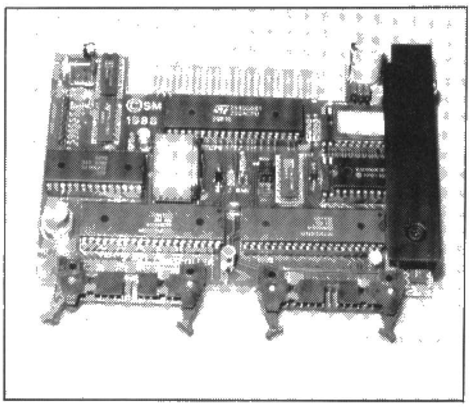
Miscellaneous:
K_1;K_2 = PCB mount terminal block.
Heat-sink for Th1.
ABS PSU enclosure (e.g., Maplin FG41U or ElectroMail 503-571).
PCB Type 87200 (not available ready-made through the Readers Services).

non-loaded) at the set speed — the reverse EMF is then virtually equal to the gate potential. In that case, the total energy consumption of the motor is, in principle, only due to compensation of internal mechanical and electrical losses. When the motor is loaded, however, its speed, and with it its reverse EMF, decreases, causing the thyristor to be fired earlier. Consequently, more energy is fed to the motor, so that its speed is corrected until the set level is reached.
The type of speed control described above works well at relatively low speeds only because it requires a fairly large drive margin. Evidently, full speed compensation for a heavy load becomes more difficult to achieve as the set speed approaches the maximum speed (in this case, about 50% of the real maximum).

Construction

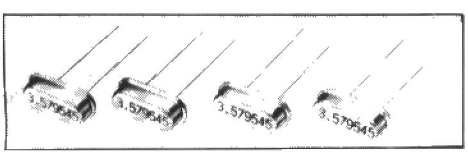
The printed-circuit board shown in Fig. 2 has been designed to ensure that the speed control circuit can be built in a simple, yet safe, manner. The size of the completed board is such that it is readily fitted in an ABS power-supply enclosure with moulded mains plug. Since the circuit is connected direct to the mains, and carries lethal voltages, it should NEVER be used until the enclosure is properly closed.
Although the stated thyristor can control loads up to 3,500 VA, it is recommended to fit it with a TO-220 style heat-sink when loads over 800 VA are connected. The connections between PCB and mains pins of the enclosure, and those between PCB and the load, are made with the aid of PCB-mount terminal blocks. For 240 and 220 V mains networks, it is imperative that C_1 has a AC voltage rating greater than 250 V, or 400 VDC. Inductor L_1 is a ready-made suppressor choke for thyristor circuits. Its inductance is fairly uncritical, and can be any value between 20 and about 100 μH. Potentiometer P_1 must be a wire-wound type with a plastic shaft.

NEW PRODUCTS



Z8O controller board

SM Engineering have announced a Z80-based single board controller and a range of DC and stepper motor control boards. They are also able to provide suitable motors for use with the boards. The Z80 controller board is available at special introductory prices from £ 94.95 to £ 108.95 depending on the amount of RAM fitted.
SM Engineering • 'St. Georges' Lion Hill Stone Cross • PEVENSEY BN24 5ED.

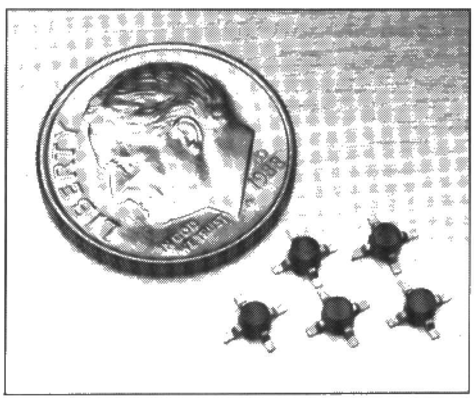


New microprocessor crystal

A low new profile microprocessor crystal from Total Frequency Control, assembled in a standard HC-49/U case, has a case height of only 4 mm. Stock frequencies are 3.57 MHz to 20 MHz and custom frequencies are available to special order.
Total Frequency Control Ltd • P.O.Box 1004 • STORRINGTON RH20 3YU.

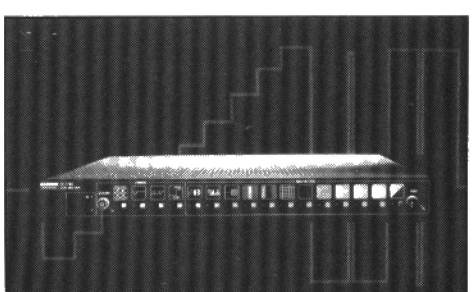
ISDN devices

National Semiconductor and SGS-Thomson Microelectronics have introduced a number of new devices specially designed for ISDN and digital telephone applications. They include second-generation PCM codec and filter devices, a digital adaptor, a monolithic transceiver, and others. They represent the initial results of a long-standing technology agreement between National and SGS-Thomson.



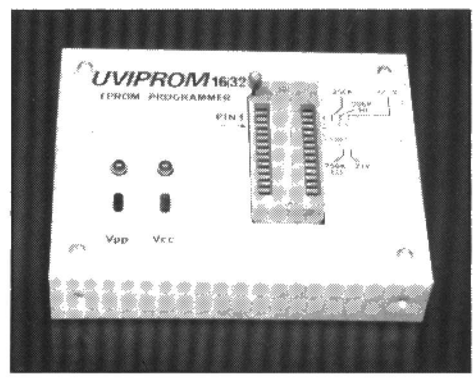
Silicon MMICs for SMT

Avantek has introduced seven cascadable silicon bipolar MMIC amplifiers housed in a low-cost, surface-mount plastic package. These MMICs are general-purpose 50-Ω gain blocks intended for use in narrow- or broad-bandwidth IF and RF amplifier designs.
Wave Devices • Laser House • 132-140 Goswell Raod • LONDON EC1V 7LE. For Avantek distributors outside the UK, see the January 1988 issue of *Elektor Electronics*.



New version OTDR

Schlumberger Instruments has announced a new version of its 7725 Optical Time Domain Reflectometer that has an improved dynamic range to extend one-way measurement distance to an unprecedented 70 km. The improvement, designed to provide the user with flexibility to evaluate 60 km links, is achieved with no trade-off on solution, which remains 1 metre over the full range.
Schlumberger Instruments Division • Victoria Road • FARNBOROUGH GU14 7PW.



EPROM programmer

The new UVIPROM 16¼32 EPROM programmer is a reasonably priced, easy-to-use unit for the BBC, B+ or Master microcomputer, enabling programming of 2764, 27128 and 27256 EPROMs, including CMOS and "A" versions. It is available ex-stock at £ 30.00 (incl. VAT and p&p) from
Ground Control • 4 Alfreda Avenue • Hullbridge • HOCKLEY SS5 6LT.

Correction Automatic diagnostics for Jaguar

Our news item on p. 62 of the October 1988 issue gave the impression that Datac jointly developed the diagnostic system with Cirrus and Jaguar. This is not the case: the system was developed by Cirrus and Jaguar, with Datac supplying only the printer.
Also, the address for further information should have been **Datac PLC, Tudor Road, ALTRINCHAM WA14 5TN, Telephone 061-941 2361.**
We apologize to all parties concerned for any inconvenience caused.

DECODING ICs FOR CD PLAYERS

Although the majority of popular compact-disc players on the market offer 16-bit×4 times oversampling, it is by no means certain that this is the standard for the future. Philips-Valvo have introduced new decoding chips that may herald the third generation compact-disc player offering 1-bit×256 times oversampling.

Figure 1 of *Pitch Control for CD Players*[3] showed the block schematic of a typical second-generation compact-disc player. The signal processing (decoding) section of that diagram is repeated in Fig. 1 of this article. It consists of four special CD ICs and a standard DRAM. For the third-generation CD player, the four special CD ICs have been replaced by two new ICs as shown in Fig. 2.

The current SAA7220 is a phase linear, 4× oversampling digital filter with 120 filter coefficients. Its frequency response is shown in Fig. 3. In conjunction with the Type TDA1541 16-bit digital-to-analogue converter and the Type TDA1542 third-order analogue filter, it has a ripple of only 0.02 dB in the pass band and an attenuation of >50 dB outside the pass-band. It is not ideal for use with de-emphasis circuits.

The SAA7220 also interpolates the values of missing or uncorrectable samples. It can estimate up to eight such samples as shown in fig. 4. The figure also shows that the SAA7210 decoder provides a basic interpolation function prior to the SAA7220.

For good sound quality, both efficient error correction and good linearity of the Type TDA1541 digital-to-analogue converter are vital. This IC contains two complete 16-bit D-A converters that, like the earlier TDA1540, operate on the well-known current division principle. Since each of the stereo channels has its own converter, there is no time delay between their signals. The conversion time is shorter than 2 μs, so that data rates of more than 6 Mbit/s can be processed.

By periodic overlapping of the two D-As on one chip, it is possible to achieve a sampling rate of 380 kHz per channel. As a matter of fact, in some CD players the TDA1541 provides 16-bit×8 times oversampling.

The SAA7220 is connected to the TDA1541 via a so-called I²S (Inter-IC-Sound) bus. This consists of a clock line, a serial data line, a control line, and a

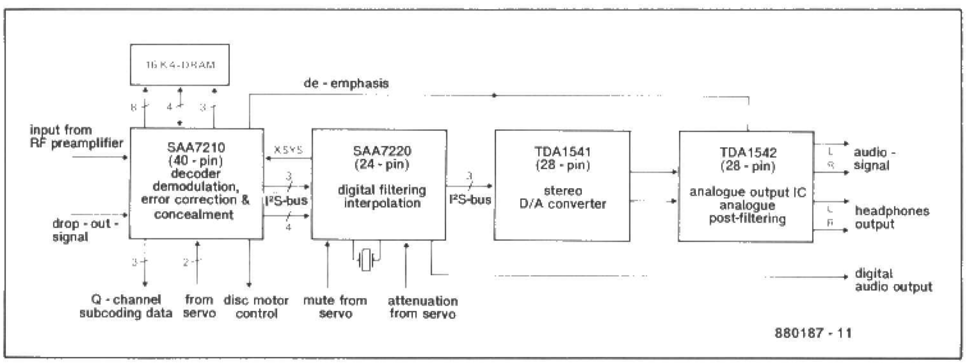


Fig. 1. Block diagram of the decoder and digital-to-analogue converter in a typical second-generation CD player.

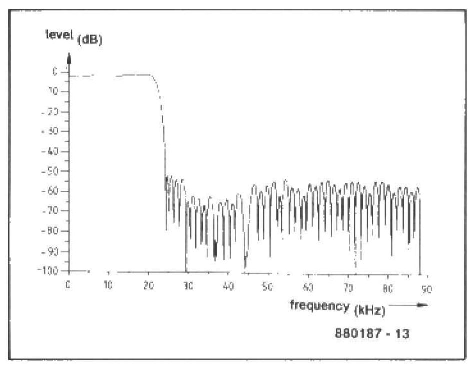


Fig. 3. Frequency response of the digital filter in the SAA7220.

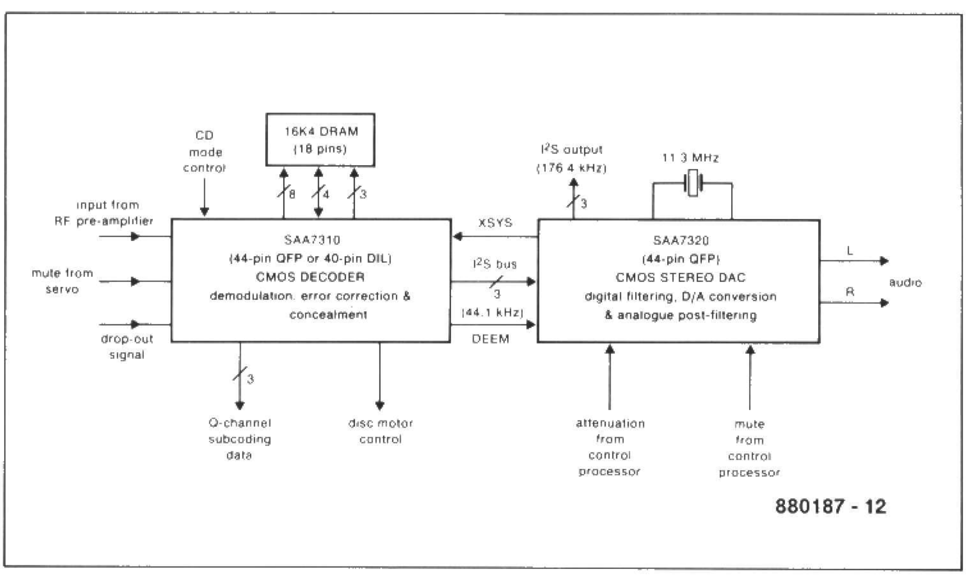


Fig. 2. Block diagram of the decoder and digital-to-analogue converter stages in a third-generation CD player: five chips have been reduced to three.

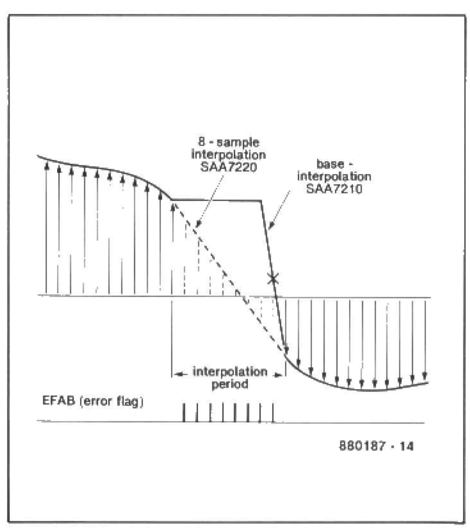


Fig. 4. The SAA7210 provides basic interpolation of uncorrectable sample values. The SAA7220 then equalizes up to 8 sequential sample values by linear interpolation.

line that connects the system clock in the SAA7220 to the SAA7210 (where the clock is connected to the disc motor servo). The control line serves to indicate whether the data pertain to the left-hand or right-hand channel.

The Type TDA1542 third-order low-pass filter also has provision for a matching amplifier and a driver stage for headphones output.

The internal circuit of the TDA1542 and the external components required to form it into a Thomson-Butterworth third-order low-pass filter are shown in Fig. 5. Its frequency response is shown in Fig. 6. Without de-emphasis, the cut-off frequency is about 45 kHz, so that in the CD transmission range up to 20 kHz ripple and phase shift are very small.

When the sound reproduction has de-emphasis, the TDA1542 is provided by the SAA7210 with an appropriate control signal that actuates the de-emphasis elements via opamps A_2 and A_2'. The response is then as shown by the dashed line in Fig. 6. It has a number of lower cut-off frequencies which cause a noticeable phase shift. The equalizing characteristic and the equality of the two channels is then determined largely by the tolerance of the external resistors and capacitors, so that fairly large deviations from the nominal values may result. This fact is normally ignored during the testing of CD players. It would be interesting to see the frequency response of CD players that have de-emphasis. It must be admitted that there are not many of these, however. It is even so that, for instance, Cambridge Audio Systems have removed the de-emphasis circuits from their latest high-end CD player.

Network L_1-C_3 forms a notch filter for appropriate attenuation of the 156.4 kHz harmonics at the output of the D-A converter.

A complete circuit diagram of a typical decoder circuit found in many popular CD players is given in Fig. 7. Instead of the not yet widely used TDA1541, two dual opamps Type NE5532 are used to form the analogue filter. The de-emphasis circuits are actuated by relay contacts K_1 and K_2. The relays are energized by driver T_2 at the DEEM output of the SAA7210.

The stereo signal is available at outputs a and d. There is no provision for headphones outputs.

It is worth noting that in this circuit, as well as in that of Fig. 5, electrolytic capacitors are used in the signal path. This was also the case in the Philips CD players used for the research of this article. It only goes to show that if you don't know there are electrolytic capacitors in the signal path, you don't hear their presence! None the less, Walter Jung, who, as Matti Otala, became well known in the 1970s by his articles on a.f. opamps and amplifier

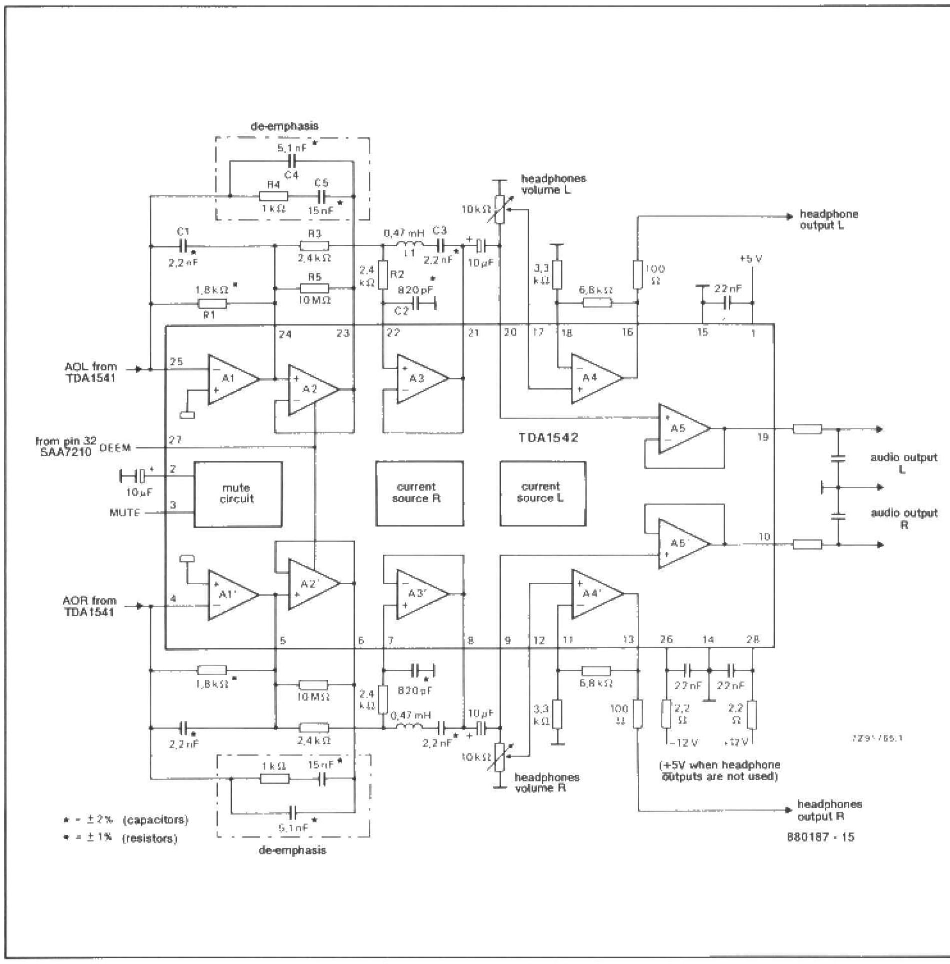


Fig. 5. Internal circuit of the TDA1542 together with the external components required to make it into a third-order low-pass filter.

techniques, gives his recommendations for reconstructing these circuits without the use of electrolytic capacitors in the January 1988 issue of *The Audio Amateur*.

Third generation CD

As already shown in Fig. 2, in the next generation CD player, the SAA7310 performs the same functions as the current SAA7210: demodulation, full error correction, and basic interpolation of uncorrectable audio samples. In addition, it controls the new data interpolation inhibit and the data concealment process. The SAA7320, which replaces the SAA7220, the TDA1541 and the TDA1542, includes a phase linear digital low-pass filter, two newly designed high-linearity D-A converters and opamps for analogue post-filtering. Like the SAA7220, it has facilities for attenuating the audio output by 12 dB, which can be used at the start of *fast forward/fast reverse* commands and a search for a track, for instance. In addition, the soft mute facility that can be used when moving to another track and during pauses is retained.

As already stated, the data format between the SAA7310 and SAA7320 is according to the inter-IC sound specification, I^2S. The I^2S bus is a 3-line bus comprising clock, serial data line, and a

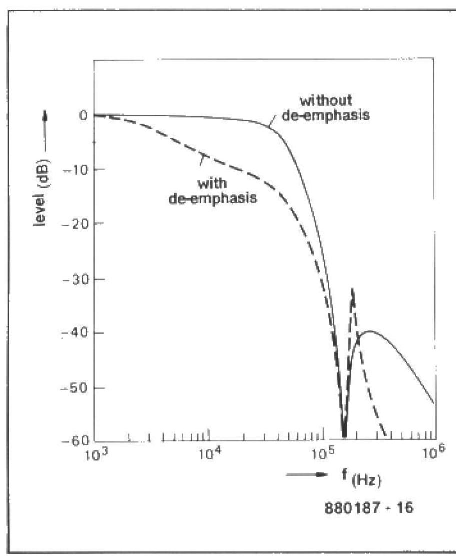


Fig. 6. Transfer function of the filter in Fig. 5 with and without de-emphasis.

control line used to select right-hand and left-hand channel words. The I_2S format allows combinations of second- and third-generation ICs to be used in a CD player, giving the player manufacturer maximum design flexibility.

Apart from having fewer ICs, the third-generation players draw a much smaller current, since the new chips are all made in CMOS technology and intended for surface mount production. The SAA7310 is, however, also available in a DIL package. The new chips should,

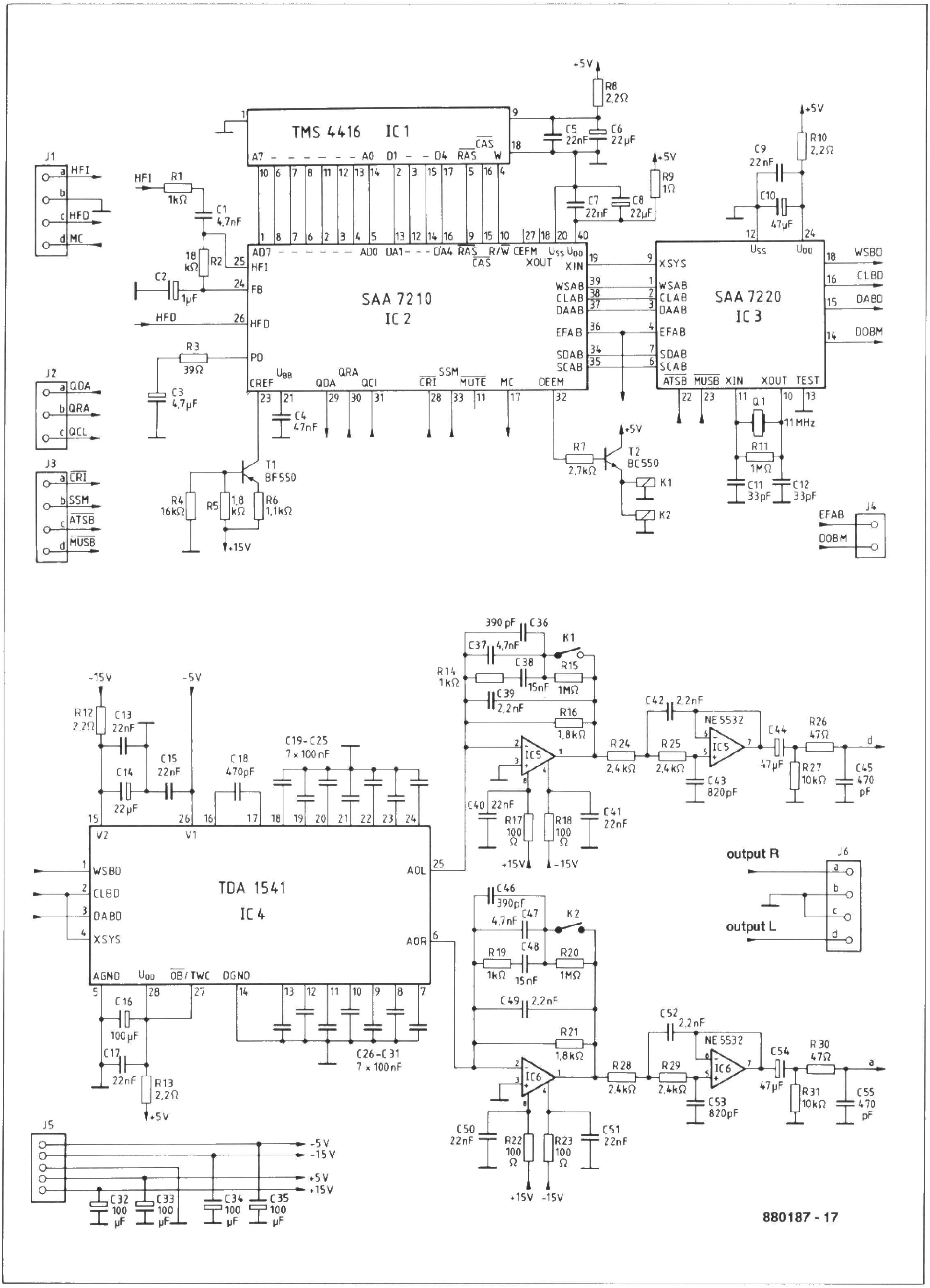


Fig. 7. Circuit diagram of the decoder and digital-to-analogue converter stages in a typical second-generation CD player.

Table 1.
Decoding ICs for CD players

	de-modulation	error correction	interpolation basic	interpolation enhanced	digital-filtering	D/A conversion	application
1st generation	SAA7010	SAA7020	SAA7000	—	SAA7030	2 x TDA1540 plus discrete analogue low-pass filter	home players
2nd generation	SAA7210		SAA7220			TDA 1541 plus TDA1542	home and full-performance players
3rd generation	SAA 7310			—	SAA 7320		portable and home players
2nd & 3rd generation	SAA 7310		SAA 7220			TDA1541 plus TDA1542	full- performance players

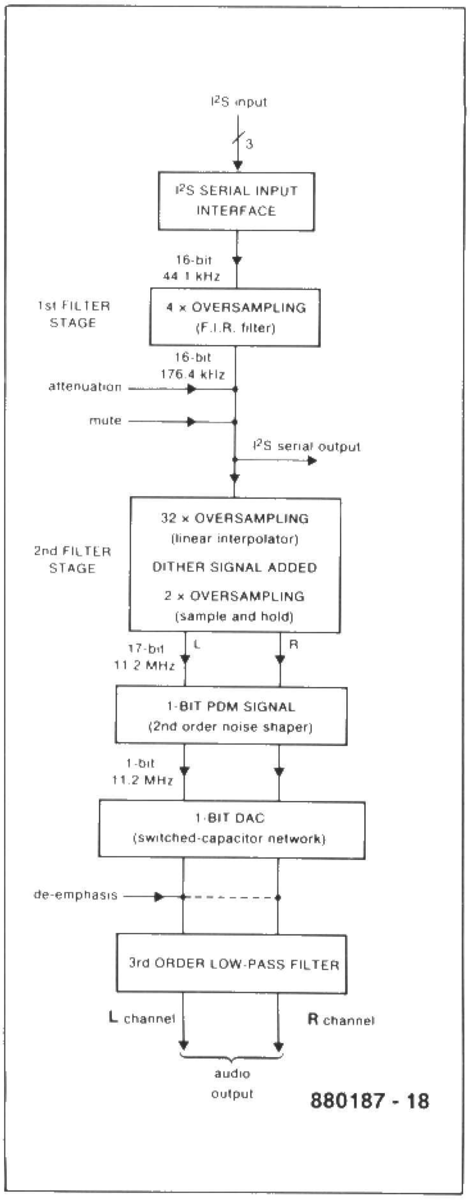


Fig. 8. Block schematic of the data flow in an SAA7320.

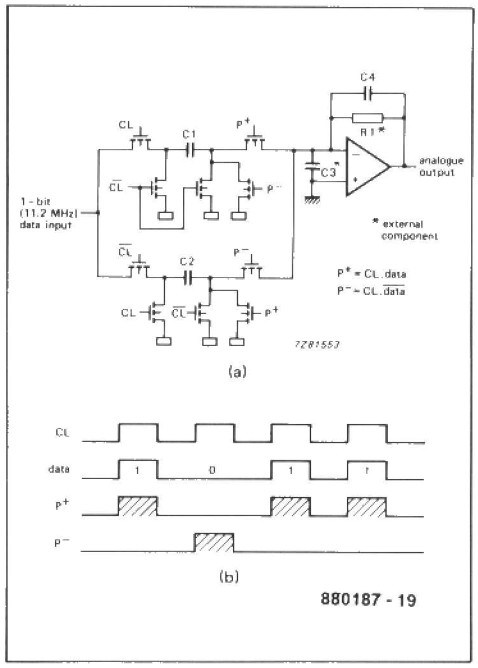


Fig. 9. Circuit diagram of the 1-bit digital-to-analogue converter in the SAA7320.

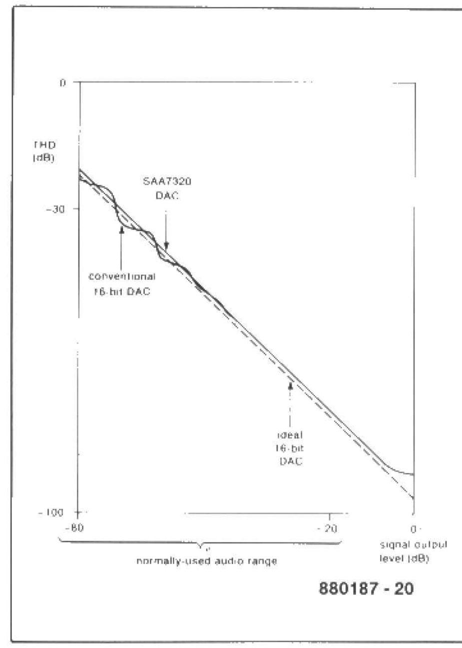


Fig. 10. At low signal levels, the linearity of the 1-bit system is better than that of a conventional 16-bit D-A converter.

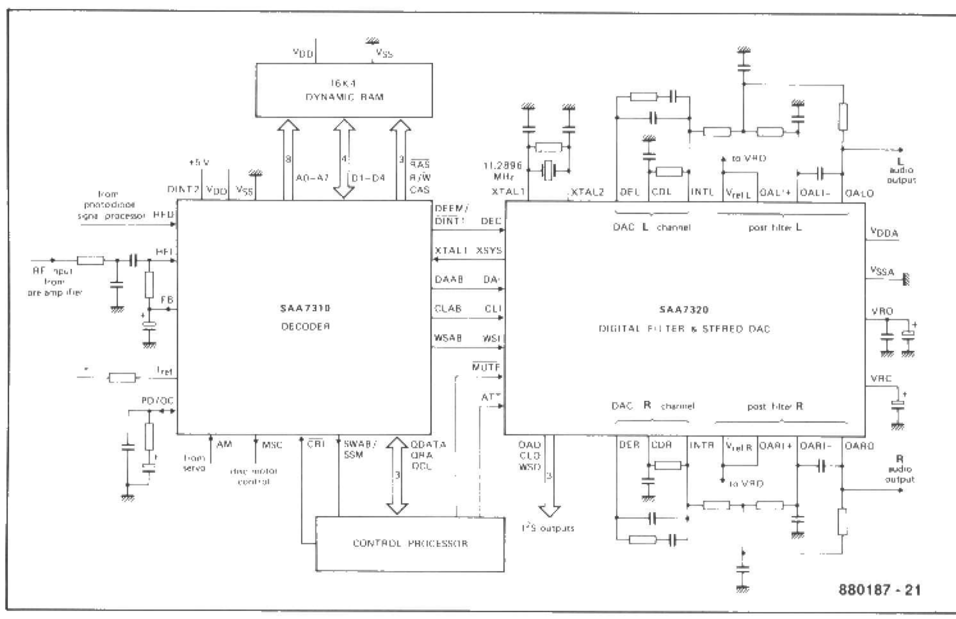


Fig. 11. Schematic diagram of the decoder, D-A converter and analogue filter in a third-generation CD player. Compared with second-generation circuits, as in Fig. 7, it has far fewer components.

therefore, make possible the production of inexpensive, high-quality portable and mobile CD players. The possible combinations of current and new-generation chips are given in Table 1.

The data flow in the SAA7320 is given in block schematic form in Fig. 8. The first filter stage corresponds to that in the current SAA7220, but has 128 filter coefficients instead of 120. The filter is followed by an I²S output so that operation with a TDA1541 as D-A converter is possible. The remainder of the IC is then not used.

The 4× oversampling filter is followed by a further oversampling filter (64×; first 32× by linear interpolation and the 2× by sample-and-hold). An internally generated noise resembling dither signal is added to the signal to reduce quantization distortion at low signal levels. This increases the amplitude, however, so that after interpolation 17-bit wide samples ensue.

The 256× oversampling process therefore provides 17-bit words at a sampling frequency of 11.28 MHz (=191.76 Mbit/s). A 1-bit quantizer reduces the 17

bits to 1 bit per sample. (A quantizer is a circuit that selects the digital subdivision into which an analogue quantity is placed, i.e., a sort of A-D converter). The resulting rounding-off error is fed back to the input of the quantizer, whose correcting action reduces the quantization noise so that only a minute part remains in the audio range. In practice, this technique works so well that the signal-to-noise ratio with 1-bit×256 times oversampling corresponds to that of a conventional 16-bit D-A converter without oversampling.

The actual 1-bit D-A converter consists of a very simple circuit with switched capacitors as shown in Fig. 9. During the first half of the sampling period, depending on the logic state of the data input, capacitor C_1 is charged (drawing current from the inverting input of the opamp) or C_2 discharges (sending current into the inverting input of the opamp). During the second half, the process is reversed.

The linearity of such a 1-bit converter can be superior to that of a conventional D-A converter. On the one hand, there are fewer converter stages and thus fewer tolerances, and on the other, the LSBs become more accurate. These LSBs normally cause non-linearity and thus distortion at low signal levels—see Fig. 10. Because of the superior linearity at small signal levels, the 1-bit system may well offer advantages (acoustically speaking) over the less-precise 16-bit D-A converter.

The opamp in Fig. 9 that serves as a current-to-voltage converter and also as a first-order low-pass (6 dB/octave) filter is followed by an opamp for each channel. Each of these opamps forms a second-order filter with external components—see Fig. 11.

These opamps operate from 5 V and have a slew rate of 30 V/μs and a signal-to-noise ratio of more than 100 dB.

A further, third-order (18 dB/octave) filter in each channel ensures an optimum flat frequency response over the audio range of 2 Hz to 20 kHz and a high (60 kHz) cut-off frequency. Furthermore, there is no phase shift at frequencies below 20 kHz.

References.

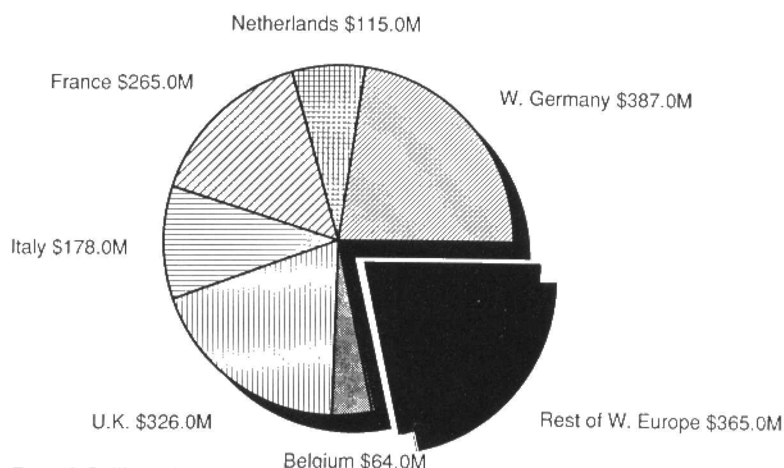
1. *The compact disc — Elektor Electronics*, July/August 1987, p. 39.
2. *Philips-Sony digital audio interface — Elektor Electronics*, June 1988, p. 14.
3. *Pitch control for CD players — Elektor Electronics*, December 1988, p. 21.
4. *Third-generation decoding ICs for CD players* — Philips Technical Publication 261 (1988).
5. *Philips-Magnavox CD player modifications* by W. Jung and H. Childress, *The Audio Amateur*, January 1988, p. 7.

NEWS

Intelligent buildings in Europe

The skyscrapers of Europe will have brains by 1992 says a report from Frost & Sullivan, *Building Control and Management in Europe.* It continues to say that the incorporation of an integrated system of telecommunications, office automation, and building services management is "on the horizon" and that there has been a recent and accelerated trend towards integrating such disparate things as heating, ventilation and air conditioning (HVAC), fire alarms or controls, and access controls. The report forecasts that the highest growth rate will occur in the UK, closely followed by West Germany.

BUILDING CONTROL & MANAGEMENT SYSTEMS MARKET IN WESTERN EUROPE - 1992



SOURCE: Frost & Sullivan, Inc.
Report #E981

Two-channel Satcom terminal on trial

A new ship earth station—SES—capable of providing two simultaneous telephone or telex calls through the same antenna is undergoing type-approval tests and will then be installed on the Cunard cruise ship *Queen Elizabeth 2* during its imminent refit.

The Marconi SES, known as Oceanray 2C, consists of the same components as the company's Oceanray 2, but has a new dual RF unit mounted beneath the antenna.

According to Marconi, the development vindicates the original unorthodox design concept of Oceanray 2, which kept the RF equipment outside the antenna, since it now leaves space to increase the relevant components. The new antenna system will, however, be enclosed within a mushroom-shaped radome to cover the extra components, distinguishing it from the spherical radome of the single-channel unit.

The installation on the QE2 is intended as a commercial trial by Marconi, although Cunard say that, subject to satisfactory operation and performance, they intend to buy it. Cunard is then also expected to decide whether to order

IBA team awarded J J Thompson medal

The J J Thompson medal for 1988 has been awarded to the development team at the Independent Broadcasting Authority who created the MAC/Packet Colour Television System.

The acronym MAC stands for Multiplexed Analogue Component system, which is a technique that avoids cross-colour defects and has many other important advantageous features. For instance, it overcomes many of the deficiencies of present television standards, makes the optimum use of the internationally agreed satellite channels and offers significant prospects for future developments involving wide screens and high definition.

STC Services stock Siemens instrumentation

STC Instrument Services has signed an agreement with Siemens to stock a comprehensive range of PC-based intrumentation.

The STC Instrument Services 320-page catalogue now lists instrumentation from more than 65 suppliers.

AUTONOMOUS I/O CONTROLLER

This concluding instalment of the article deals with serial interface hardware at the host computer side, and software command descriptions.

Final Part

The RS232-to-current loop converter shown in Fig. 12 is the same as that used in the microcontroller-driven power supply. A discussion of its operation and application can be found in Ref. 1. Constructional details are shown in Figs. 13 (printed-circuit board) and 14 (practical version, ready for fiting inside the hood of a male D-25 connector). Pins 4 and 5 of non-used D9-connectors should be interconnected to prevent breaking the current loop. The adaptor allows up to 6 instruments to be connected to the bus, but only if the host computer supplies ±12 V at its RS232 outlet. Some computers supply only 5 V, which limits the number of instruments that can be connected to 2 or maybe 3.

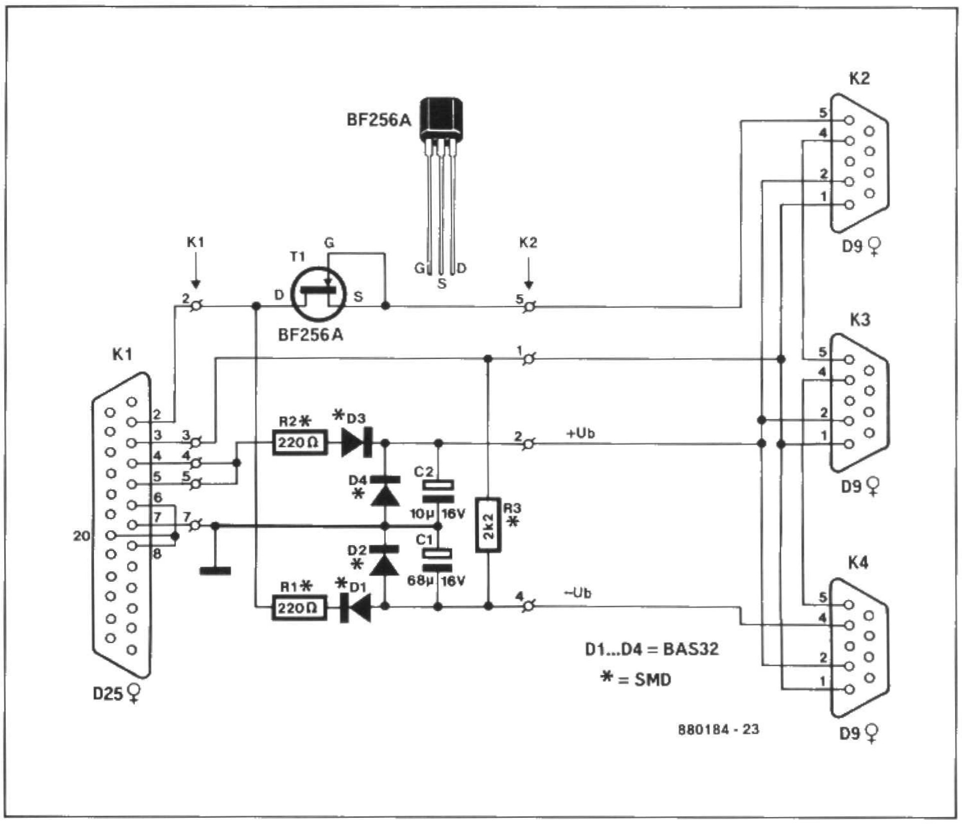


Fig. 12. Circuit diagram of the RS232-to-current loop converter.

Selective addressing

The bus structure designed for the automous I/O controller and the microcontroller-driven power supply (Ref. 1), allows individual addressing of equipment with the aid of selection codes, which are in the range from 128 to 155. When an instrument selection code is sent via the bus, the central processor in each bus-connected instrument is interrupted to compare the current code with its own identification code. As shown in Table 2 (see Part 1) each type

Parts list

ADAPTOR BOARD. CIRCUIT DIAGRAM: FIG. 12

Resistors (SMA types):
R1;R2 = 220R
R3 = 2K2

Capacitors:
C1 = 68µ; 16 V; miniature axial.
C2 = 10µ; 16 V; miniature radial.

Semiconductors:
D1;D2;D3 = BAS32 (= SMA version of 1N4148)
T1 = BF256A

Miscellaneous:
K1 = 25-way female sub-D connector with hood.
K2 = 9-way male sub-D connector with hood.
PCB Type 880016-4 (see Readers Services page).

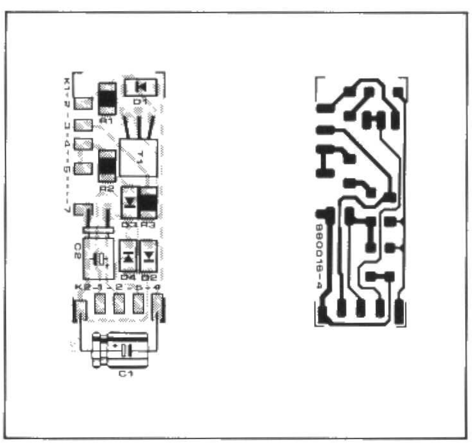


Fig. 13. True-size track layout and component mounting plan of the RS232-to-current loop adaptor. The circuit is built mainly in surface-mount technology. To facilitate soldering, the component overlay is not actually printed on boards supplied through the Readers Services.

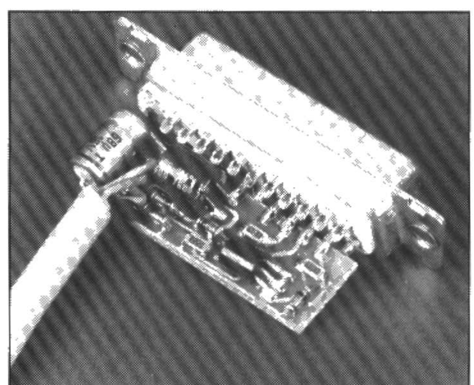


Fig. 14. The adaptor circuit is so small that it can be housed in the hood of a female D25 connector plugged into the host computer's RS232 outlet.

of instrument can be assigned one of four addresses. This is done to enable the use of up to four instruments of a particular type (in this case, an I/O controller or a microcontroller-driven power supply).

When the I/O controller recognizes its identification code on the bus, LED REMOTE CONTROL lights to indicate that the serial interface is available for transmission and reception of commands and data to or from the host computer.

Figure 2 in Part 1 of this article shows that the serial interface in the I/O controller is based on a pair of optocouplers to ensure complete electrical insulation from other bus-connected devices. It should be noted that production tolerance on the optocouplers is relatively high. In certain cases, therefore, the values of R20 and R22 may have to be changed to ensure a sufficiently low digital level.

Serial interface commands

The serial data format and speed is 9600 baud, 1 start bit, 8 data bits, 2 stop bits and no parity bit.

General:
Three types of command are available:

- Identification codes to enable serial communication with an instrument, after interrupting its 'off-line' operation. Reserved codes are 128 to 255. The autonomous I/O controller can be assigned an address between 144 and 151.
- Commands to read data from the I/O controller. These commands are given in lower-case letters. The controller's response is a parameter in decimal notation (or in hexadecimal in certain cases). Voltage readings are expressed in volts (V), preceded by non-significant leading zeroes where applicable.
- Single-character commands, e.g., N<CR> to switch to the NO LOCAL mode. The I/O controller sends nothing in return (except, in certain conditions, the echoed command).

When ECHO ON is selected, the I/O controller returns all received commands. Incorrect characters or syntax errors, however, are returned in the form of a question mark.

Identification code
Each bus-connected instrument is configured to recognize a particular odd-numbered and an even-numbered address. The first effectively switches the instrument 'off-line', the second 'on-line' (see Table 2).

Even-numbered address (on-line; listen)
The host computer can select the I/O controller, i.e., switch it 'on line', by sending the address (between 144 and 150) that corresponds to the configuration of diodes D_1 and D_2 on the main PCB. Provided the I/O controller is in ECHO ON mode, the selection code is returned to the host computer. Also, LED REMOTE CONTROL on the front panel is turned on, and remains on until the 'off-line' (quit) code is received.

Odd-numbered address (off-line; quit)
Serial communication with the I/O controller is terminated by the host computer sending the 'off-line' (quit) address immediately after the 'on-line' address. Assuming that the instrument identification code is 144, reception of address 145 disables serial communication with the host computer. Listen and quit codes need not be followed by a <CR>. The I/O controller never echoes the quit code when this is recognized and accepted, even when ECHO ON is selected. The instrument can only be brought on-line again by the host computer sending the appropriate even-numbered address.

Status byte request
To prevent the computer sending inappropriate or improperly timed commands to the I/O controller, this supplies a status byte of configuration shown in Table 3. The computer can call up the status byte by sending command NUL (control-@ or 00_H, not ASCII 0), which is never echoed.

Table 3

STATUS BYTE		
Bit	1	0
B0	echo on	echo off
B2	ready	not ready
B3	outputs disabled	outputs enabled
B4	local	no local
B1 = 1; B5 = B6 = B7 = 0 shaded areas denote default settings		

The host computer should always read the status byte, and wait until bit b2 is high (ready) before sending a new command to the I/O controller. Command NUL itself is never echoed. Instead, NUL prompts the I/O controller to immediately send the status byte. Example:

00_H *command received by the I/O controller*
16_H *status byte returned by the I/O controller.*

With reference Table 3, this means that: the I/O controller is in LOCAL mode and ready to accept a new command, the digital outputs are enabled, and ECHO is turned off.

Note: in the ECHO ON mode, reception by the host of the echo of the CR used for ending each command does not guarantee the actual execution of this command. When the command returned has been subject to normal echoing (i.e., characters are sent back in their true form, not as '?'), the echo of the CR merely indicates that the command *has been received correctly, and is executable*. Whether or not the command has actually been executed can only be ascertained by calling up the status byte.

The highest value of the status byte sent by the I/O controller is $1F_H$ (ECHO ON mode; ready; digital outputs disabled; LOCAL control). The lowest value is 02_H (ECHO OFF mode; not ready; digital outputs enabled; NO LOCAL mode).

General-character commands
■ **CR** and **CANCEL** (ctrl-X; 18_H)
Each command, with or without parameters, should be ended with a CR (carriage return; $0D_H$), **not a CR-LF** (carriage return followed by line feed $0A_H$), which will not be accepted by the I/O controller. CANCEL can be sent at any time in the string, but before the closing CR, to prevent an erroneous command being executed. CANCEL is echoed just like any other character.

Error message sent by the I/O controller
■ **?**
When the I/O controller is in ECHO ON mode, it replaces incorrect characters with a question mark, i.e., the incorrect character sent by the host computer is not echoed. The returning of a '?' means that the command that contained the incorrect character has been cancelled. For example, when the I/O controller receives string U1,10.1A, it returns U1,10.1?, and does not execute command U1,10.1. The I/O controller does not accept any new command until it has received a CR or a CANCEL command.

Commands without parameters
■ **R<CR>**
R stands for RESET. The result of this command is the same as switching the I/O controller off and on again. Note that the serial interface is then switched off-line, so that the last character received on the host computer is the echoed CR following R (provided, of course, ECHO is ON).

N<CR>
N stands for NO LOCAL. This command inhibits the push-button on the front panel of the I/O controller until

the reception of command LOCAL (L) or RESET (R). Following the reception of the quit code (odd-numbered instrument address), LED REMOTE CONTROL remains on when the I/O controller is in NO LOCAL mode. This is so arranged to provide an indication when the push-button on the front panel is effectively disabled. The LED goes out when either one of the above mentioned reset conditions is met, or when the unit is switched off and on again, which automatically resets it to the default configuration.

L<CR> L stands for LOCAL. This command enables the push-button on the front panel. The I/O controller defaults to LOCAL after power-up.

X<CR>
This command selects ECHO ON mode. It is particularly useful when the I/O box is controlled by means of a terminal, or a computer acting as a terminal. The I/O controller defaults to ECHO ON after power-up.

Y<CR>
This command selects ECHO OFF mode. ECHO is best turned off when the host computer executes a program that simultaneously uses several instruments on the bus. ECHO is effectively turned off **after** the command itself, Y<CR>, has been echoed. This means that the question mark (syntax or transmission error) is not echoed afterwards.

C<CR>
This command forces all digital outputs of the I/O controller to logic low. Note that the digital outputs are of the open-collector type: a logic low level, therefore, turns off the output transistor, so that its collector voltage is almost the supply voltage.

D<CR>
This command forces all digital outputs of the I/O controller to logic high. Note that the digital outputs are of the open-collector type: a logic low level, therefore, turns on the output transistor, so that its collector voltage is practically nought.

Commands with parameters
General note: although the decimal point in the syntax of the parameters is only processed as a delimiter by the microcontroller in the I/O controller, it is essential, and facilitates progamming the host computer because it makes the parameter syntax compatible with that of BASIC (in particular, instruction PRINT USING).

The analogue outputs are numbered 0 to 3; the analogue inputs 0 to 7. The digital outputs are numbered 0 to 31 in 4 blocks of 8; the same goes for the digital inputs.

Contrary to the protocol used for the microcontroller-driven power supply, the autonomous I/O controller does allow two-parameter commands, e.g., output number followed by logic level, or output number followed by analogue voltage. The default for the second parameter is nought. Data for the digital input and output channels on the I/O controller can be sent in decimal or hexadecimal. The latter format is useful when the unit is controlled direct by a terminal. Decimal notation, on the other hand, is advantageous when BASIC is being used.
Syntax verification is automatic and works on a character-by-character basis while commands are being loaded. Parameters in hexadecimal notation should be preceded, not followed, by the letter h or H.

Single-parameter commands
The parameter is the number of the output, or the block of outputs.

a<n><CR>
Parameter *n* is given either in decimal (0 to 31) or hexadecimal (H0 to H1F). This command enables reading the state of a logic output. The I/O controller returns a 0 when the output is logic low, and a 1 when the output is logic high.
Examples:
a7<CR>
reads the state of the last output line in block 0;
a8<CR>
does the same for the first output line in block 1.

b<0 to 3><CR>
This command enables reading the state of the eight digital outputs in a block.

Table 4

Command	Parameter 1	Parameter 2	Answer	Command description
[144...150]	–	–		even-numbered address enables serial communication
[141...151]	–	–		odd-numbered address disables serial communication
R	–	–	–	initialization
L	–	–	–	mode LOCAL
N	–	–	–	mode NO LOCAL
X	–	–	–	mode ECHO ON
Y	–	–	–	mode ECHO OFF
C	–	–	–	all digital outputs to logic 0
D	–	–	–	all digital outputs to logic 1
a	⟨0 to 31⟩	–	⟨0 or 1⟩	read digital output level
b	⟨0 to 3⟩	–	⟨0 to 255⟩	read block configuration byte (8 outputs)
e	⟨0 to 31⟩	–	⟨0 or 1⟩	read digital input level
f	⟨0 to 3⟩	–	⟨0 to 255⟩	read block configuration byte (8 inputs)
g	⟨0 to 3⟩	–	⟨0 or 1⟩	read block interconnection status (0 = off; 1 = on)
u	⟨0 to 3⟩	–	⟨0 to 10.23⟩	read programmed analogue output voltage
v	⟨0 to 7⟩	–	⟨0 to 10.23⟩	read analogue voltage applied to input
G	⟨0 to 3⟩	–	–	interconnection in block enabled
H	⟨0 to 3⟩	–	–	interconnection in block disabled
A	⟨0 to 31⟩	⟨0 or 1⟩	–	write logic level to output line
B	⟨0 to 3⟩	⟨0 to 255⟩	–	write byte to block of output lines
U	⟨0 to 3⟩	⟨0 to 10.23⟩	–	write voltage to analogue output

The I/O controller returns data in the form of 4 characters.
Eaxmples:
b0<CR>
reads the state of the output lines in block 0. Assuming that these are all logic 1, the I/O controller answers:
0255
Similarly, in hexadecimal, command
bh0<CR>
would result in answer
H0FF
The answer represents the programmed, not the actual, levels on the outputs. This means that the answer to command **b** does not take the DISABLE OUTPUTS function into account.

e<n><CR>
Parameter *n* is given either in decimal (0 to 31) or hexadecimal (H0 to H1F). This command reads the logic level applied to a digital input (see command **a** above for syntax and answer descriptions).

f<0 to 3><CR>
This command enables reading the state of the eight digital inputs in a block (see command **b** above for syntax and answer descriptions).

g<0 to 3><CR>
The answer to this command informs the host computer whether or not inputs and outputs of identical number in the stated block are interconnected (answer: 1) or not (answer: 0).
The interconnection is a software function of the I/O controller, which is capable of detecting falling pulse edges (transition from 1 to 0), on digital inputs in the interconnected block. The software arranges for the corresponding output to toggle, and remain in the new state until a further high-to-low transition is detected. Key debouncing (max. 5 ms) is also ensured by the program, making it possible to have push-buttons, connected direct to the inputs of an interconnected block, control loads (LEDs; relays) on the corresponding outputs.
Example: command:
g2<CR>
Answer:
1
indicates that block 2 is in interconnected mode.

u<0 to 3><CR>
This command reads the set output voltage relevant for the stated analogue output.
Example:
Assuming that analogue output 0 has been programmed to supply 9.99 V, commands
u0<CR> and
uh0<CR>
both prompt the I/O controller to answer
09.99
This means that the answer is always in decimal notation.

v<0 to 7><CR>
This command reads the voltage applied to the stated analogue input.
Example: command
v6
returns
09.10
to indicate that input 6 is driven with an analogue voltage of 9.1 V.

G<0 to 3><CR>
This command results in interconnection of corresponding lines in the stated block. The interconnection works even in the NO LOCAL mode, but not when the digital outputs are disabled manually by pressing key DISABLE OUTPUTS (LED is turned on).
Example: command
G1<CR>

H<0 to 3><CR>
This command effectively ends the interconnection of corresponding inputs and outputs in the stated block.
Example: command
H2<CR>

Two-parameter commands
The two parameters involved are separated by a comma. The first paramcter is the number of the output, or block of outputs. The second parameter is the desired logic level, combination of logic levels, or analogue output voltage.

A<n>,<0 or 1><CR>
Parameter *n* is given either in decimal (0 to 31) or hexadecimal (H0 to H1F). This command programs a logic level (0 or 1) on the stated output (*n*).
Examples: command
A,<CR>

```
10 REM *********** TEST PROGRAM 2 DEVICES ***********
20 PWR = 132: IO = 144:      REM device addresses
30  CLS
40 :
50 REM If any file open, close it
60  CLOSE
70 :
80 REM Open communication port 'COM1:' (9600Bd, no parity, 8 bits, 2 stopbits)
90 REM as file number 1.
100  OPEN "com1:9600,n,8,2" AS 1
110 :
120 REM Delay (minimal .2s) to get correct interface voltage.
130  FOR DELAY=0 TO 1000: NEXT
140 :
150 REM Initialize and close all devices.
160  FOR ADDR = 128 TO 254 STEP 2
170   PRINT#1, CHR$(ADDR);CHR$(&H18);"R";CHR$(&HD);
180  NEXT ADDR
190 :
200 REM Clear host RxD-buffer.
210  WHILE NOT(EOF(1)):DUMMY$=INPUT$(1,#1): WEND
220 :
230 :
500 REM ************* MAINPROGRAM ***************
510  ADDR=PWR: CMND$="U": NROFVARS=1: VAR1=500: GOSUB 1000:      REM 5V
520  ADDR=PWR: CMND$="I": NROFVARS=1: VAR1=10: GOSUB 1000:       REM 100mA
530  ADDR=PWR: CMND$="D": NROFVARS=0: GOSUB 1000:                REM no 0V out
540  X=1:
550  WHILE X<=128
560 REM set one output of block 0
570   ADDR=IO: CMND$="B": NROFVARS=2: VAR1=0: VAR2=X: GOSUB 1000
580   REM test value of analog input 0, loop if < 1.5V
590    ADDR=IO: CMND$="v": NROFVARS=1: VAR1=0: GOSUB 1000: VOLTAGE = I
600    LOCATE 1,1: PRINT"Analog input 0: U=";:PRINT USING"##.##";VOLTAGE
610    IF VOLTAGE < 1.5 GOTO 580
620   X=X*2:        REM select next output
630  WEND
640  ADDR=IO: CMND$="C": NROFVARS=0: GOSUB 1000:              REM all outputs 0
650  ADDR=PWR: CMND$="C": NROFVARS=0: GOSUB 1000:             REM 0V out
660 END
670 :
680 :
1000 REM ************** OUTPUT COMMAND *****************
1010 REM
1020 REM Open device 'ADDR', check status, transmit command if ready and
1030 REM close device.
1040 REM On exit 'I' contains the requested value (if any).
1050 REM
1060  PRINT#1, CHR$(ADDR);:                          REM open device 'ADDR'
1070   PRINT#1,CHR$(0);: STATUS=ASC(INPUT$(1,#1)):   REM get status
1080   IF (STATUS AND 4)=0 GOTO 1070:                REM loop if not ready
1090 REM ********** Transmit command and variables (if any) **************
1100  PRINT#1, CMND$;
1110  IF NROFVARS >= 1 THEN PRINT#1, VAR1;:          REM first variable
1120  IF NROFVARS >= 2 THEN PRINT#1, ","; VAR2;:     REM second variable
1130  PRINT#1,CHR$(&HD);:                            REM <CR>
1140 REM ********** Get variable if requested **************
1150  IF (CMND$ <= "z") AND (CMND$ >= "a") THEN INPUT#1, I
1160  PRINT#1,CHR$(ADDR+1);:                         REM close device
1170 RETURN
```

880184 - 28

Fig. 15. Sample GWBASIC listing that illustrates the way in which one microcontroller-driven power supply and one autonomous I/O controller may be operated with the aid of commands sent via the instrument bus.

or

A0,0<CR>

programs a logic low level on digital output 0. Command

A1,1<CR>

programs a logic high level on digital output 1.

B<0 to 3>,<n><CR>

Parameter *n* is given either in decimal (0 to 255) or hexadecimal (H0 to HFF). This command enables simultaneous programming of all 8 outputs in a block. The first parameter is the block number, the second the desired 8-bit pattern (in decimal or hexadecimal).

Examples: command

B,<CR>

or

B0,0<CR>

sets all output lines in block 0 to logic low. Command

B1,HA0<CR> results in binary pattern 1010 0000 on the output lines in block 1.

U<0 to 3>,<n><CR>

Parameter *n* is either 0 to 1023, or 0 to 10.23. This command programs the desired output voltage on the stated analogue output. The first parameter is the number of the output, the second a value between 0 and 10.23 (V) or 1023 (mV).

Examples: commands

U,<CR>

and

U0,00.00

both result in 0 V on analogue output 0. Commands

U1,.23<CR>

and

U1,00.23<CR>

both result in 230 mV on analogue output 1. Commands

U2,3.40<CR>

and

U2,03.40<CR>

both result in 3.4 V on analogue output 2.

Note that the 0 following 4 in the previous example is significant: command

U2,3.4<CR>

is the same as

U2,.34<CR>

and both result in 340 mV, not 3.4 V, on analogue output 2.

Finally, command

U3,10.23<CR>

results in 10.23 V on analogue output 3.

Sample program and final remarks

The GW-BASIC listing in Fig. 15 is given here to aid programmers getting started with developing application-oriented software for the host computer. The sample program enables an IBM PC or compatible to control two bus-connected instruments: a microcontroller-driven power supply (Ref. 1) and an I/O controller as descibed in this article.

At the end of this article we once more advise readers that the control program in the Type 8751 microcontroller is protected by copyright. Listings can, therefore, not be made available. Ready-programmed, copy-protected, 8751's are available through the Readers Services.

References mentioned here can be found at the end of Part 1.

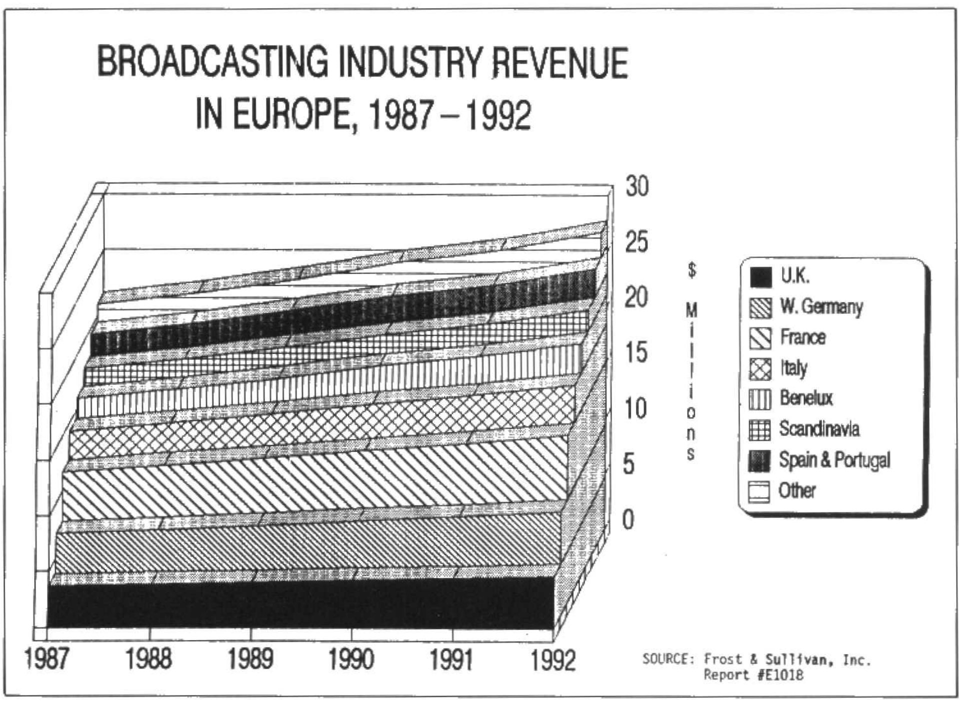
NEWS

New digital services

A new digital communications service providing business customers with high-speed PBX connections to System X electronic local exchanges was launched by British Telecom recently.

These connections will support the new generation of digital electronic switchboards known as integrated services private branch exchanges (ISPBXs), now becoming available from all major suppliers in the United Kingdom. They will link ISPBXs into British Telecom's integrated services digital network—ISDN.

Broadcasting equipment market in western Europe



A study by Frost & Sullivan estimates that the broadcasting equipment market in western Europe will increase by nearly a third to $27.8 billion by 1992.

Increases in transmission equipment have accompanied the spread of VHF radio. In 1987 there was a total of 2,660 main VHF transmitters (excluding relays) in western Europe. Most, 610, were in Scandinavia. The study forecasts the total to increase to 3,275 by 1992. The greatest growth will come in Spain and Portugal, from 440 in 1987 to 715 in 1991.

In the television sector, the study predicts an increase in the total number of main transmitters from 1,620 in 1987 to 1,905 by 1992. Only the Benelux countries will remain static at 40 transmitters. The number of television receivers is forecast (conservatively) to increase from a total of 136 million in 1987 to 174 million by 1992.

DESIGN IDEAS

The contents of this column are based solely on information supplied by the author and do not imply practical experience by *Elektor Electronics.*

DESIGNING BAROMETERS FROM SIMPLE CIRCUITRY

by E.A. (Babs) Barber* and Scott Weatherwax

Two different types of low-cost, solid state barometers can be designed with the Sensym SCX15ANC absolute pressure sensor. The first uses a 15-volt power supply and produces an analogue output voltage, that is proportional to the barometric pressure, which can be easily scaled to respresent mBar, mmHg or inHg. The second uses a 9-volt battery with a 3½ digit LCD display signal output. This gives a portable, digital barometer which could be used by a hiker.

Analogue voltage output example (scaled in mBar)

To construct a barometer with an output voltage directly proportional to the barometric pressure, the circuit shown in Figure 1 is required.

Amplifier A_1 is used to supply a 10 V regulated voltage to the sensor. In this manner, the circuit becomes independent of variations in the 15 V power supply. Amplifier A_2, in conjunction with potentiometer R_3, provides altitude convection (offset adjustment). The final two amplifiers, A_3 and A_4, are connected as an instrumentation amplifier providing gain to the sensor output. The gain equation is given by:

$$V_o/V_i = A_o = 2(1 + R_T/R_1)$$

Design calculations

The barometer is to be scaled in mBar. The output voltage of the circuit shown in Figure 1 can be scaled so that it corresponds directly to a barometric pressure in mBar (1 psi = 68.947 mBar).

For example:

At 1013.8 mBar (sea level) the output = 10.138 V.

Thus:

At 1310.3 mBar the output = 13.103 V. Using this direct scale, it is seen that a 10 mV change is equal to a 1 mBar pressure change, so that a 296.5 mBar reading will result in a 2.965 V change. The value of gain resistor R_T is calculated from the gain equation. The output span of the SCX15ANC for 15 psi is equal to 90 mV when operating from a 12 V supply. This eventually equates to 0.5 mV per-volt-per-psi.

At 10 V and a change of 296.5 mBar (4.3 psi), the output of the sensor will change 21.5 mV. Because it is required that a 296.5 mBar pressure change gives an output voltage change of 2.965 V, the gain needed is 137.9 V/V. Using equation 1, and making R_1 equal to 10 kΩ, the gain resistor R_T is found to be 147 Ω.

A fixed 137 Ω resistor and a multiturn 20 Ω potentiometer are used for R_T: this allows for circuit tolerance and provides accurate adjustment of the gain. The values of resistors R_S and R_G are given in Table 1.

Calibration

Two methods can be used for calibrating the barometer. Both need a brief explanation of the underlying mathematical principles before the adjustment procedure is defined.

At a given supply voltage, the output voltage of the sensor is:

$$V_o = (S \times P) + V_{os}$$

Where V_o = output voltage (mV)
S = sensor sensitivity (mV/psi)
P = applied pressure
V_{os} = sensor offset voltage (mV)

The sensitivity can be determined by using two known pressures, since this results in two equations and unknown values of V_{os} and S.

At atmospheric pressure

$V_{01} = [S \times P_{atm}] + V_{os}$

If a known pressure of 2 psig is applied:

$$V_{02} = [S \times (P_{atm} + 2\ psig)] + V_{os}$$

S does not change as a function of applied pressure, so:

$$V_{02} - V_{01} = S \times 2\ psig\ \text{or:}$$

$$S = (V_{02} - V_{01})/2\ \text{volts/psi}$$

The offset can be calculated by:

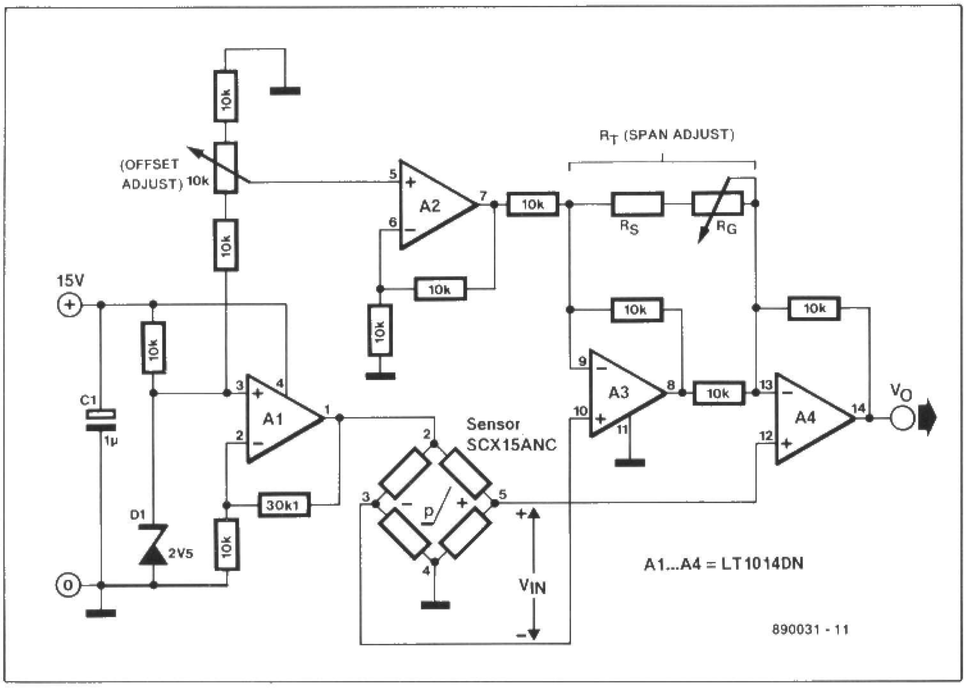
$$V_{os} = V_o - /S \times P_{atm}$$

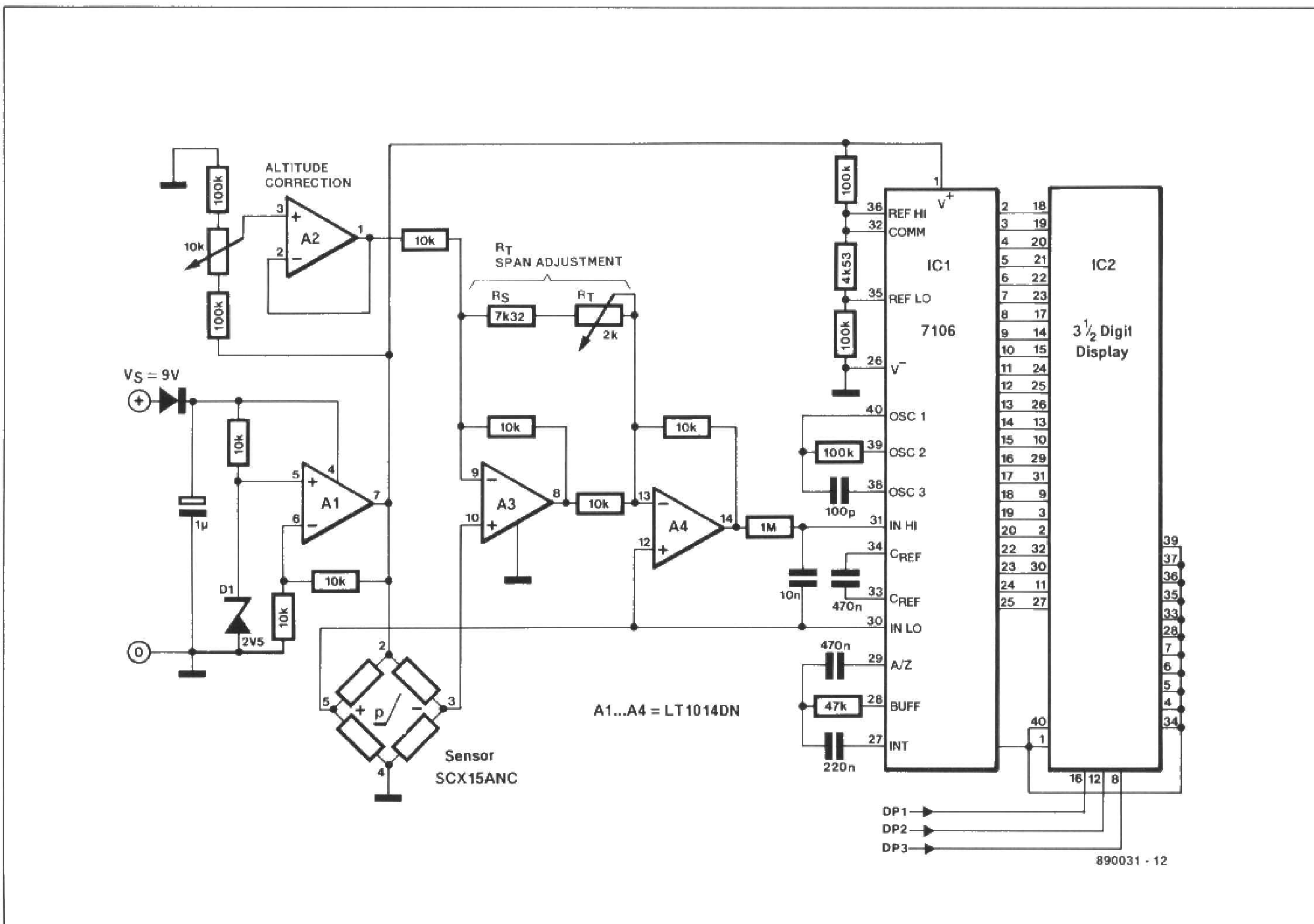
When the offset is known, R_3 can be adjusted to minimize its error contribution. The remaining error is caused by

* E.A. (Babs) Barber is with Hi-Tek Electronics.

Table 1
Resistor Values RS and RG for Analog Output Barometers

Unit	Gain	Nominal Resistor Value	RS	RG
mBar	138 V/V	147 Ω	137 Ω	20 Ω
mmHg	103 V/V	197 Ω	174 Ω	50 Ω
inHg	41 V/V	517 Ω	464 Ω	100 Ω
inH2O	55 V/V	375 Ω	348 Ω	50 Ω
kPascal	138 V/V	147 Ω	137 Ω	20 Ω





span which can be eliminated by adjusting R_T until the digital output display reads the same as the actual barometric pressure.

Procedure one

The first procedure assumes that an additional pressure source is available, and this makes adjustment of the gain and offset voltage much easier.

The barometer is turned on and left to warm up for about 10 minutes. The digital reading should be recorded at the end of this period. The actual barometric pressure must be obtained from a reliable source. The known second pressure source should be applied and the output recorded. Now the offset and span can be calculated from the two above-mentioned pressure points within the mathematical model. The span potentiometer should be adjusted to minimize its error contribution followed by offset adjustment until the digital display output exactly matches the barometric pressure obtained.

Procedure two

With the second procedure it is not necessary to have access to a source other than barometric pressure, although the adjustment will be less accurate and the source of error, either off-

set or span, will be unknown.

The value of R_T is calculated, and the nearest value nominal fixed gain resistor is used without a gain potentiometer. Following this, offset potentiometer R_3 is adjusted to agree with the actual barometric pressure.

An error of approximately 3% can be expected without the precise span and offset adjustment. If the barometer is to be used just for relative pressure changes, this will not be critical.

mmHg barometer

The output can easily be scaled to mmHg (1 psi = 51.714 mmHg) by using the same circuit with a recalculation of the value of R_T.

For the above example, the output range would have been from 5.689 V (568.87 mmHg) to 9.826 V (982.59 mmHg). Thus, for 413.73 mmHg, a change of 4.137 V is required. When the same method used in the previous example is apllied, R_T is found to be 197.2 Ω. The adjustment is the same for the mBar-scaled barometer.

A portable barometer

The schematic diagram in Figure 2 shows a portable digital barometer with a 3½ digit LCD display.

Amplifier A_1 supplies a regulated 5 V to the sensor and display driver. Accuracy will not be affected until the battery has dropped below 6.5 V. Offset adjustment is provided by amplifier A_2 and potentiometer R_4. Amplifiers A_3 and A_4 are connected as an instrumentation amplifier, where the full scale output is adjusted by R_G. An ICL 7106 analogue-to-digital converter, with a built-in display-driver, is provided to interface the circuit and the 3½ digit liquid crystal display. The same gain equation as before is used, where $R_1 = 10$ kΩ.

Design calculations

The output to the A-D converter will represent the barometric pressure in PSI. From the Sensym data sheet, the full scale output of the sensor, at 15 psia, is 90 mV. Since the output voltage is proportional to the supply voltage when powered by a 12 V supply, the resulting full scale output, at 15 psia, will be 37.5 mV using a 5 V supply.

If the full scale output of the A-D converter is considered to be 166 mV, the resulting voltage gain required is 4.4 V/V. R_T is calculated to be 8.26 kΩ from the gain equation. A fixed 7.23 k resistor and a multiturn 2 kΩ potentiometer are used for R_S and R_G to allow for circuit tolerance and the precise adjustment of the gain.

Final construction technique

When all of the values are known, the final construction can take place. To minimize noise and errors in temperature, this should be carried out on a solder board. The connections to the display are all shown, apart from that of the decimal point. This can be simply achieved by connecting the point to a permanently displayed LCD segment.

For example, with a PSI output, the decimal point should be connected to the lbc segment of the most significant digit, as this is always powered under normal barometric conditions.

Adjustment procedure

The adjustment procedure is exactly the same as the first procedure used in the analogue voltage output model where an additional pressure source is available.

To null both the span and offset error, a two point calibration procedure is suggested. If the second pressure source is not available, the use of a fixed value for resistor R_T will give a fairly accurate result.

Conclusion

This article has highlighted two types of barometer that can be constructed from the Sensym SCX15ANC and amplifier circuitry, but many more types can be built.

The direct-voltage-read-out barometer is a good laboratory instrument, whereas the portable version is, of course, intended for use out of doors. Both versions may be built from cost-effective components that guarantee reliable results.

NEWS

Distributing TV by millimeter Wave Radio

British Telecom's Research Laboratories have successfully demonstrated the use of short-range millimetre-wave radio for delivering programmes into viewers' homes.

If the system were licenced by the Government, it could prove a quick and economic supplement to broadband cable networks. It could bring multi-channel TV to millions of homes that are unlikely to be cabled before 2000.

The system uses a frequency of about 30 GHz to beam four satellite TV programmes plus the four broadcast services to a number of homes in a town fitted with special antennas capable of receiving the transmissions. Commercial systems would be capable of carrying between 15 and 25 channels.

British Telecom's system is made economically possible by the use of gallium-arsenide ICs. These microchips allow the receiving equipment to be built at a cost many people could afford.

Martlesham already has an established worldwide reputation for the fabrication of optoelectronic components from gallium-arsenide and is now pioneering the design and fabrication of circuits operating in the more challenging millimetre-wave bands.

They have produced Monolithic Millimetre-Wave ICs (MMWICs) on a single semiconductor wafer, which in production can contain hundreds of individual microcircuits. They have also harnessed the properties of high dielectric constant ceramic resonators to achieve cost-effective stabilization of the millimetre-wave oscillators.

Martlesham research workers estimate that, with the economies of large-scale production, receivers would be produced for about a few hundred pounds. These receivers use a dish only 15 cm in diameter, much smaller and more environmentally acceptable than the 30-100 cm dishes needed to receive TV programmes direct from satellites. They are capable of receiving a mix of programmes drawn from:

- TV receive-only or direct broadcasting satellites at several orbiting positions;
- off-air UHF broadcast channels;
- cable TV programmes;
- taped programmes injected at the head end;
- high definition or extended-definition TV when available;
- local interest and community programmes.

In addition, the system may be easily configured for either PAL or MAC formats. Also, it would allow different satellite programmes to be viewed on different sets.

GEC National One in UK field trials

The availability of mobile radios suitable for the new GEC National One Network has resulted in important field trials by BBC Transmission and Atlasair Parcels Service Ltd.

The BBC is to subject a number of Marconi RC6309 radios to full field trials by transmitter maintenance teams in the West Midlands.

Network One already offers interconnecting communications from Cheltenham to Dover and from Liverpool to Southampton. The greater part of the United Kingdom will be covered by the end of this year.

A LOW-COST DEVELOPMENT SYSTEM FOR M6805 MICROPROCESSORS

by Peter Topping

Development systems for single-chip MCUs can be complex and expensive, dissuading potential users of this type of microprocessor from designing them into new applications. This article describes a low-cost 'entry' development system for debugging hardware and software for Motorola's M6805 range of microprocessors.

The M6805 range includes both CMOS and NMOS parts, all but one of which are single-chip devices which include mask-programmable ROM, RAM, I/O and a timer function. The exception is the CMOS MC146805E2, which has no on-chip ROM but has a multiplexed data/address bus that enables it to use external memories and peripherals.
The development system described uses the MC146805E2 processor, and can be used to develop applications intended for the MC146805G2, MC146805F2, or the E2 itself. It can also be used for applications intended for NMOS variants such as the MC6805P, U and R families, or the more recent CMOS devices such as the MC68HC05C4 and the MC68HC05B4/6, but does not emulate all the features of these devices, since without the addition of external chips, there is no A-D (R&B families) or SCI/SPI (HC05s).
There is an EPROM or EEPROM version of most M6805 devices. These versions allow prototyping or limited volume production without the need for mask programming. They can be used to check the operation of the software in the final application PCB without the additional hardware required for an emulator.
An example of software and hardware developed with the system can be found in Ref. 1.

M6805 DBUG05 Development System

- Inspection/modification of RAM locations.
- Inspection/modification of all registers.
- Up to three breakpoints.
- Tracing (through RAM or EPROM).
- Relative offset calculation.
- Program save/load using cassette tape.
- Real-time clock routines.
- 24-key keyboard and 6-digit display (which can be used from user software).
- Example software shows how to debug programs introduced on EPROMs as an alternative to using the cassette interface.
- All-CMOS (battery operation).

Introducing the MC146805E2

The MC146805E2 has a multiplexed bus which requires an address latch to interface with non-multiplexed RAMs, ROMs, and EPROMs. Even with this type of bus it only has sufficient pins to provide two I/O ports. The MC146805G2 includes a further two ports. With an MC146805E2, these can be supplied by a PIA such as the MC146823. Alternatively, the latch, additional ports and the address decoding logic can all be provided by an MC68HC25.
The MC146805E2 can thus be used with an MC68HC25 to build a system of only three chips (E2, HC25 and EPROM). Such a system would be most cost-effective in small volume applications not justifying a mask-programmed single-chip MCU. For software development, however, RAM and a monitor system have to be incorporated so that memory locations can be examined and changed. The 6116 2 Kbyte static RAM is used here, while the DBUG05 EPROM fulfills the monitor requirement.

Circuit description

The circuit diagram of the development system is given in Fig. 1. The 6116 2 Kbyte RAM is placed between \$0000 and \$07FF. This means that the 128 bytes from \$0000 to \$007F are not used, as they are mapped over the E2's I/O and RAM space. This mapping was chosen to fully utilize the address space in which the direct addressing mode of the MC146805E2 can be used. It has the disadvantage, however, that there is a conflict at addresses \$0002, \$0003, \$0006 and \$0007 where the MC68HC25 adds ports C and D (ports 3 and 4 in the MC68C25). This can be resolved by decoding out the bottom half of page zero in the RAM chip-select/output-enable logic as shown in the circuit diagram. The 74HC32 in conjunction with the 74HC00 inverts the data strobe supplied by the E2, disabling the RAM when the address is in the range \$00 to \$7F.
RAM in the top half of page zero provides enough directly accessible memory to emulate the MC146805G2 (112 bytes). This is not the case without adding RAM, as DBUG05 uses 41 bytes of the E2's RAM (also 112 bytes). The 6116 RAM extends up to \$07FF; the space between \$0080 to \$00EF is used to emulate the G2 RAM, and from \$0100 to \$07FF for the software under development. The second block of RAM will not be required when the software has been debugged, and therefore does not conflict with the recommendation that the space between \$0100 and \$06FF should not be used with the MC68HC25. MC74HC00s provide the address decoding and the R/W and output enable signals for the RAM, the low-order addresses being demultiplexed by AS using the MC68HC25.
A 27C16 2 Kbyte EPROM is selected by CS2 from the MC68HC25 between \$0800 and \$0FFF, and can be used to introduce software which has been entered and cross-assembled on a PC, or manually by an EPROM programmer.
The address range between \$1000 and \$17FF is not used except for the (optional) MC146818 real-time clock (RTC), which is required to be at \$1700 if the DBUG05 RTC routines are to be used.

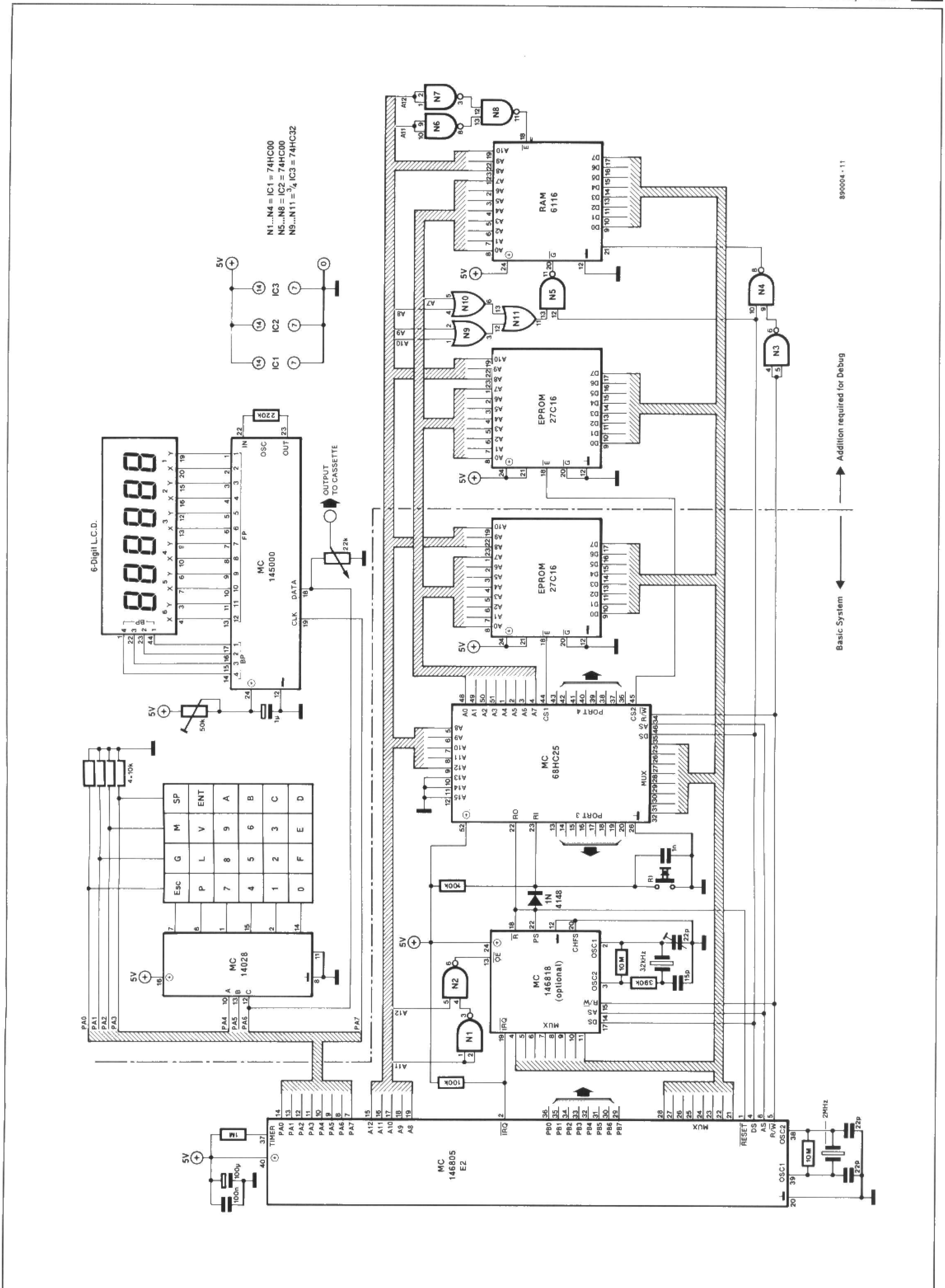


Fig. 1. Circuit diagram of the MC146805E2-based M6805 development system. The parts outside the dashed lines are required for DBUG05.

An MC74HC138 can be used to decode the RTC at $1700. Alternatively, if nothing else is required between $1000 and $17FF, a 74HC00 can be used to select an address range of $1000 to $17FF, as the RTC chip will still appear at $1700.

The DBUG05 monitor EPROM uses the memory range from $1800 to $1FFF, and can be selected by the MC68HC25's $\overline{CS1}$ chip select line. Figure 4 shows a memory map of the development system. The DBUG05 EPROM, like the user software EPROM, is shown as a 27C16, but could also be a 27C64 (or a 2716 or 2764 if the low-power capability is not required).

The monitor display is a 6-digit, 4-backplane LCD (e.g. Hamlin Type 4200, or the 8-digit GE Type LXD69D3F09KG) which is driven by an MC145000 display driver. The driver is controlled by a 2-line serial link from the microprocessor. A static LC display shown in Fig. 2 can be used as an alternative. Three MC144115 driver chips are used, along with a transistor invertor to supply the additional latch enable signal required by these drivers. This circuit requires many more connections to the LCD, but allows the use of a commonly available display.

The MC68HC25 has a RESET IN pin intended as a system reset, and a RESET OUT pin to reset the processor. For this to work, a clock is required. As the clock is supplied by the MC146805E2, a low at RESET IN will not wake the E2 from a STOP instruction, so a diode has been added between RESET IN and RESET OUT to ensure that a low on RESET IN always forces a low at RESET OUT.

The DBUG05 monitor includes routines to transfer 6805 code to and from a cassette tape. When the PUNCH (P) key is used to record a program, the output is taken from PA6 as shown in Fig. 1. When the L key is used to load a previously saved program, the output from the cassette should be applied to the interrupt pin of the MC146805E2. This signal should be between 2 and 5 V_{pp}, and be AC-coupled to the microprocessor. When this is being done, it is advisable to disconnect all other components from the IRQ pin.

MC68HC25

The MC68HC25 has many modes of operation allowing it to work with the MC6801 and MC68HC11 as well as with the E2. It can also operate with different sizes of memory map. Mode selection for the MC68HC25 is effected with the aid of data at address location $1FBF. The byte used here is $F4. Table 1 shows the options available, where 'X' indicates those used. The byte is read after RESET goes high, but before the HC25 RESET OUT goes high to start the processor.

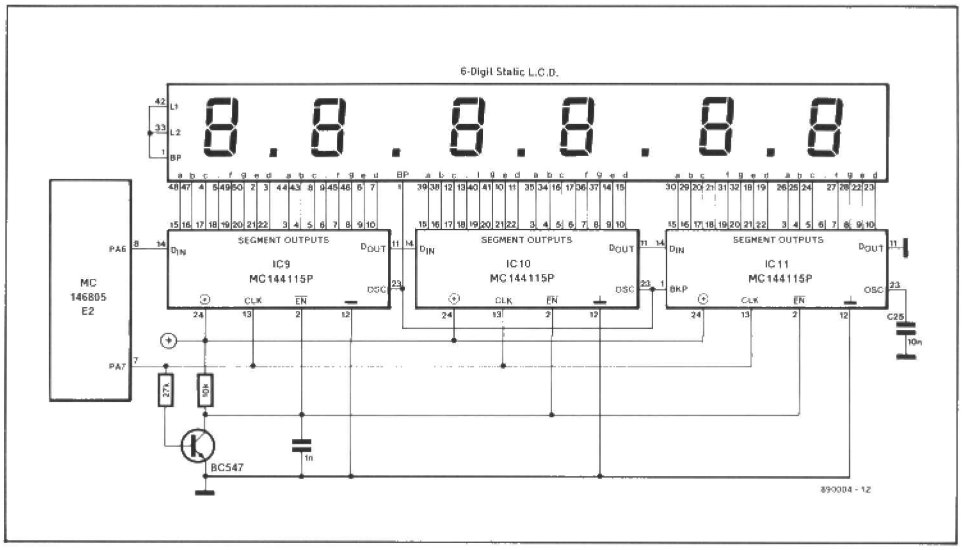


Fig. 2. Circuit diagram of the alternative, static, LC display.

If additional ports are not required, a 74HC373 octal latch can be used instead of a MC68HC25, to de-multiplex the low-order addresses. In this case, the EPROM select logic can be provided by a 74HC00. A circuit employing a 74HC373, strobed by the AS signal from the MC146805E2, and a 74HC00 for chip select, is shown in Fig. 3. Note that the use of this simple unstrobed chip select circuit requires that the EPROM output enables (pin 20) are strobed by the inverted data strobe from the MC146805E2. If the MC68HC25 is not used, the 74HC32 can be omitted (pin 13 of the 74HC00 should be connected to pin 12), as can be the mode byte at $1FBF.

If the EPROMs used are of the CMOS type, the whole system is in CMOS, and consumes only a few milliwatts when active, and a few microwatts in stand-by (with the E2 in STOP mode). In order to achieve this low stand-by dissipation, the multiplexed databus, timer pin and other uncommitted high-impedance lines should be grounded via 100 kΩ resistors. In DBUG05, port A has 4 input lines grounded through 10 kΩ resistors, and 4 output lines. Port B, however, is not configured, so all eight bits are inputs, and will increase stand-by dissipation unless held low (or high), or assigned as output in software. This also applies to ports C and D on the MC68HC25. If the final code is to be used without DBUG05, it should also configure port A's I/O lines.

Table 1. MC68HC25 Mode Selection

The mode selection byte contains the following bits:

Bit	Function	Options	
7,6	$\overline{CS2}$ address size	1,1: 2 Kbytes	X
		1,0: 4 Kbytes	
		0,1: 8 Kbytes	
		0,0: 16 Kbytes	
5,4	$\overline{CS1}$ address size	1,1: 2 Kbytes	X
		1,0: 4 Kbytes	
		0,1: 8 Kbytes	
		0,0: ---	
3	$\overline{CS1}$ zone shift	1: shifted	
		0: not shifted	X
2	CMOS/TTL	1: CMOS	X
		0: TTL	
1	Memory map size	1: 64 Kbytes	
		0: 8 Kbytes	X
0	Port displace	1: displaced	
		0: not displaced	X

System monitor DBUG05

The DBUG05 EPROM comprises a monitor specifically written to enter and debug 6805 code. Input is via a 24-key keyboard. The functions available are listed in Table 2.

The MC146805E2's vectors are within the address space of the DBUG05 EPROM. They operate via extended jumps in RAM. This gives the user access to the vectors if these jumps are written to from within the user's program. The interrupt jumps are at $40 for IRQ, $43 for timer, and $46 for timer (wait). An example of how these are used is shown on lines 17 to 20 in Fig. 5. Clearly, the RESET vector can not be altered in this way, so during debugging, user software should be started using the GO facility in DBUG05.

Example software

The example software listed in Fig. 5 has been assembled to reside in RAM starting at address $0100, but is introduced into the system in the EPROM at $0800. The code includes a routine to move itself into RAM where it can be executed and debugged using DBUG05. This provides an alternative to the cassette routine in DBUG05 intended for loading software to be debugged.

Table 2. DBUG05 functions.

Function	Key	Description of function
PC	0	Display program counter.
BP	5	Enable breakpoints. Breakpoint one is displayed if enabled, or text 'boff' if it is not. Enter new breakpoint address followed by ENTER to change or enable and move to next one. Three breakpoints are available.
BCL	6	Clear breakpoints. ENTER clears all breakpoints. Entering a number followed by ENTER clears that breakpoint only.
DT	8	Display time from (optional) MC146818.
ST	9	Set time on the (optional) MC146818 (P for PM, AM is default).
OFF	A	Calculate branch offset. The address of the branch instruction, and that of the destination, are requested. If a valid branch is calculated, it is written into memory, and displayed. If not valid, then text 'or' (for *out of range*) is displayed. A branch of −128 through +127 relative to the start address of the next instruction is allowed
TR	B	Trace one instruction.
STOP	C	Put the E2 into STOP mode. Clock stops, display clears.
CC	D	Display/change Condition Code register. New data is followed by ENTER. ESC returns to '⊓' prompt without changing contents.
XR	E	Display/change Index register. New data is folllowed by ENTER. ESC returns to '⊔' prompt without changing contents.
AR	F	Display/change Accumulator. New data is followed by ENTER. ESC returns to '⊔' prompt without changing contents.
P	P	Record tape. On pressing P, text 'ba' (for *begin address*) is displayed. Enter first address (followed by ENTER), then last address when text 'ea' is displayed. A second ENTER starts the recording.
L	L	Load tape. Press L, then play tape. Valid load displays '⊏', bad memory displays address. Checksum error displays 'err'.
V	V	Verify tape. If OK, prompt '⊓' is displayed, otherwise incorrect address, or 'err' for a checksum error.
ENTER	ENTER	Enter keyed-in address or data (and move to next address in 'M'.
ESC	ESC	Escape from current function, except STOP, V, L and P.
GO	GO	Begin or continue program. When pressed, curent PC is displayed. To proceed from that location, press ENTER. To proceed from a different address, enter the address followed by ENTER.
M	M	Display/change a location in RAM. When pressed, last address is displayed. Press ENTER to display the contents of the address, or enter a new address followed by ENTER. New contents can be entered if required. ENTER moves to next address, M moves to previous address.
SP	SP	Display stack pointer.

To achieve low dissipation in STOP mode, it is desirable to execute the STOP instruction in EPROM. This is achieved during debugging by the extended JMP on line 22. Alternatively, there is a STOP instruction followed by a branch back to this instruction at address $1FF3 in DBUG05. This is intended for use by a program in RAM, as the execution of a STOP instruction in RAM will not result in low dissipation (the RAM will be left selected when the microprocessor goes into STOP mode).

If the debugged software is required to run in EPROM without the DBUG05 EPROM, then the code should be reassembled at $1800, and the MC68HC25 mode byte and the reset and interrupt vectors added.

In the example software, lines 10-11, 17-20, 22 and 51-56 should be deleted as they are only relevant when the program is in RAM. The ORG statements on lines 6 and 9 should be changed from $0080 to $0010, and from $0100 to $1800. The EPROM should be decoded at $1800 instead of $0800 ($\overline{CS1}$ from the MC68HC25), and the DBUG05 monitor EPROM removed. If the target system uses only two ports — and can thus use a 74HC373 rather than an MC68HC25 — it may be necessary to change the port allocation to make port A available.

Clearly, the use of port A can not be debugged, but as long as the DDRs and the hardware are also changed this should not be a problem.

In the example software, the reset vector ($1FFE) should point to START (line 14), and the external interrupt vector ($1FFA) to IRQ (line 12). The MC68HC25 mode byte ($F4) should be added at address $1FBF.

If the E2's 112 bytes of RAM are sufficient for the relevant application, the 6116 RAM can also be removed. Care should be taken to leave enough RAM for the stack, which starts at $7F. Two bytes are used for each level of subroutine, and five bytes for each level of interrupt. The simple example program shown uses 7 bytes (one interrupt and one level of subroutine). More complicated programs will use more (up to a maximum of 64 bytes), but it would be unusual to use more than 20 bytes. This would leave 92 bytes of RAM available for other uses. During debugging, the stack is in the E2 at $7F, and 128 bytes of RAM in the 6116 ($80 to $FF) were available for data storage.

The monitor uses the timer and its vector for breakpoints and tracing, so if the timer is used in the application, these facilities can not be used. The timer WAIT vector is not used, and an application using it can make use of all the monitor's features except when the timer is actually running. In practice, this is not a major restriction if the timer part of the application is debugged after the rest of the software is working.

Example hardware

The previously discussed software was developed for use with the MC145157-based radio synthesizer described in Ref. 1. The divide ratio is entered into locations SMEM and SMEM+1, and is transferred to the synthesizer chip when the microprocessor is interrupted. This method allows the MC146805E2 to be in STOP mode when it is not actually sending a frequency. This arrangement eliminates any risk of RFI in the receiver. In the simple example shown, the divide ratio has to be manually converted and entered into RAM. In the complete control program for the synthesizer (see Ref. 1), this would of course be done automatically when the required frequency was entered into a keyboard. After, say, 1265 (kHz) is converted to hexadecimal ($04F1), the bits must be moved left by one place to allow for a control bit to be sent to the MC145157 after the frequency. This control bit determines whether the ratio is intended for the ref-

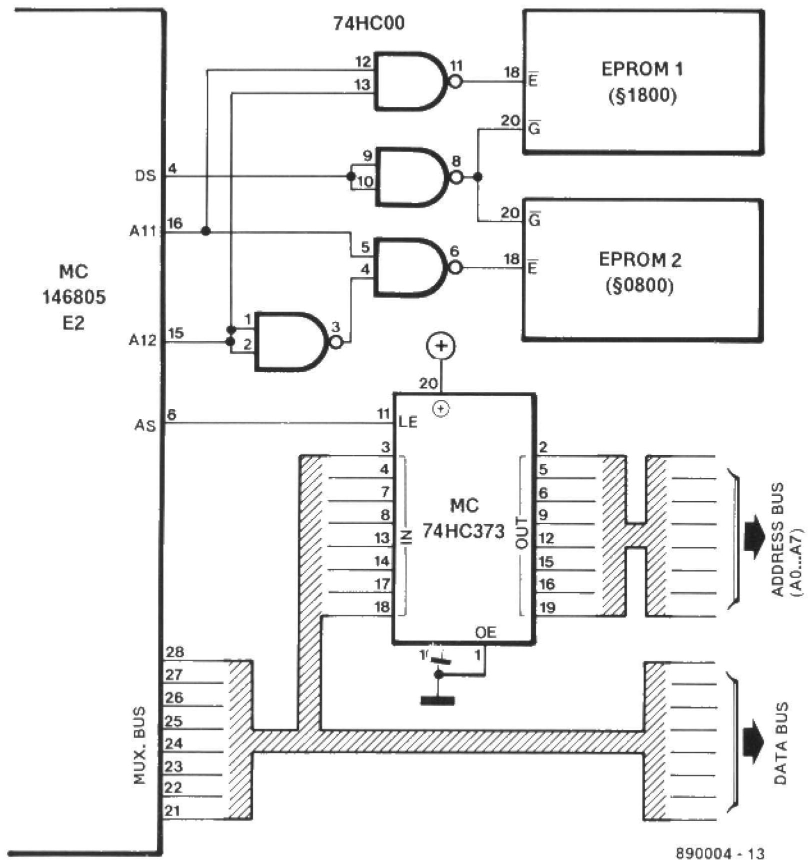
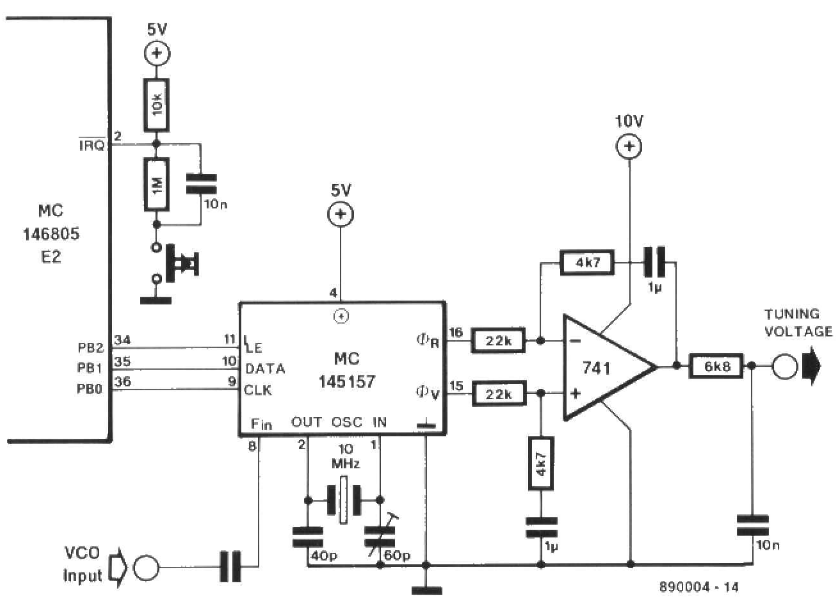


Fig. 3. This simple latch circuit provides an alternative to the MC68HC25 in applications where additional ports are not required.

Port A data	$0000
Port B data	$0001
Port C data direction	$0002
Port D data direction	$0003
Port A data direction	$0004
Port B data direction	$0005
Port C data	$0006
Port D data	$0007
Timer data register	$0008
Timer control register	$0009
not used	$000A $000F
MC146805E2 RAM (inc. STACK at $7F)	$0010 $007F
MCM65116 data RAM	$0080 $00FF
6116 program RAM	$0100 $07FF
Program EPROM (CS2N)	$0800 $0FFF
not used (optional MC146818 at $1700)	$1000 $17FF
DBUG05 EPROM (CS1N)	$1800 $1FFF

890004 - 15

Fig. 4. Memory map of the system monitor, DBUG05.



Basic synthesizer circuit that works in conjunction with the program listed in Fig. 5.

erence divider or the LO (local oscillator) divider. A zero is required for the LO divider, so SMEM and SMEM+1 contain the hexadecimal number $09E2 for a LO frequency of 1265 kHz.

The fixed reference divide ratio of 10,000 can be seen in the software listing on lines 26 and 28. The number $214E is the hexadecimal equivalent of 10,000, again moved left by one bit, but this time the control bit is a logic one.

To maximize the usefulness of the development system, a home computer capable of assembling 6805 code, and programming EPROMs, should be available. Motorola's AS5 assembler for IBM PCs and compatibles is available for this purpose. This program, and the listing of DBUG05, can be obtained free from *Elektor Electronics* by sending a formatted 5¼ inch, 360 kByte, diskette, and a self-addressed, stamped return envelope, to our Brentford office. Overseas readers please include 3 IRCs to cover the return postage.

References:

1. Microprocessor-controlled radio synthesizer. *Elektor Electronics* July/August and September 1988.
2. Motorola application note AN823A, 'CBUG05 Monitor for the MC146805E2'.

```
 1 P                                OPT    CMOS
 2 P
 3 A          0001       PORTB      EQU    $01
 4 A          0005       DDRB       EQU    $05
 5 P
 6 A          0080                  ORG    $80           Data RAM
 7 A 0080     0002       SMEM       RMB    2             MC145157 freq.(e.g. 810kC=E2,09)
 8 A
 9 A          0100                  ORG    $0100         Program RAM
10 A 0100     CC0847     MOVE       JMP    MOV+$700      start at $800 to load into RAM
11 A 0103     CC0109     RST        JMP    START         start at $103 to run in RAM
12 A 0106     CC011D     IRQ        JMP    SQRT          interrupt starts here
13 A
14 A 0109     A607       START      LDA    #$07          setup bits 0 - 3
15 A 010B     B705                  STA    DDRB          as outputs
16 A 010D     3F01                  CLR    PORTB         and clear
17 A 010F     A601                  LDA    #$01          DBUG05
18 A 0111     B741                  STA    $41           interrupt
19 A 0113     A606                  LDA    #$06          vector
20 A 0115     B742                  STA    $42           extended jump
21 A
22 A 0117     CC081A                JMP    STP+$700      execute STOP in EPROM
23 A 011A     8E         STP        STOP
24 A 011B     20FD                  BRA    STP           RTI returns here
25 A
26 A 011D     A64E       SQRT       LDA    #$4E          10 MHz/10,000 = 1 kHz
27 A 011F     AD15                  BSR    SQU           send reference MSB
28 A 0121     A621                  LDA    #$21
29 A 0123     AD11                  BSR    SQU           and LSB
30 A 0125     1401                  BSET   2,PORTB       latch
31 A 0127     1501                  BCLR   2,PORTB       it
32 A 0129     B681                  LDA    SMEM+1        local osc. MSB
33 A 012B     AD09                  BSR    SQU
34 A 012D     B680                  LDA    SMEM          and LSB
35 A 012F     AD05       SQU2       BSR    SQU
36 A 0131     1401                  BSET   2,PORTB       latch
37 A 0133     1501                  BCLR   2,PORTB       it
38 A 0135     80                    RTI                  go back into standby (STOP)
39 A
40 A 0136     AE08       SQU        LDX    #8
41 A 0138     48         S1         LSLA                 move 1 bit into "C"
42 A 0139     2402                  BCC    S2            zero?
43 A 013B     1201                  BSET   1,PORTB       no
44 A 013D     1001       S2         BSET   0,PORTB       clock
45 A 013F     1101                  BCLR   0,PORTB       it
46 A 0141     1301                  BCLR   1,PORTB
47 A 0143     5A                    DECX
48 A 0144     26F2                  BNE    S1            any more?
49 A 0146     81                    RTS
50 A
51 A 0157     AE00       MOV        LDX    #00           move
52 A 0149     D60800     T8         LDA    $800,X        program
53 A 014C     D70100                STA    $100,X        program
54 A 014F     5C                    INCX                 EPROM ($800)
55 A 0150     26F7                  BNE    T8            to RAM ($100)
56 A 0152     CC0109                JMP    START
57 A
58 A                                END

***** TOTAL ERRORS      0--
***** TOTAL WARNINGS    0--
```

890004 -16

Fig. 5. Synthesizer example software developed on DBUG05.

Events

IEE Meetings

5 Jan. Radio propagation in bad weather.
9 Jan. ASIC design on silicon.
10 Jan. Digital audio broadcast systems.
12 Jan. Whither computer-based training?
16 Jan. The changing face of telecommunications transmission.
18 Jan. Pan-European managed networks.
20 Jan. The effects and implementation of changes in electrical units.
23 Jan. Advances in the direct measurement of antenna radiation characteristics in indoor environments.
24 Jan. Computer vision for robots.
26 Jan. The UK direct broadcast satellite.
27 Jan. User interfaces and standardization.

Details on these, and many other, events may be obtained from **The Secretary • IEE • Savoy Place • LONDON WC2R 0BL • Tel. 01-240 1871.**

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9-10 Jan. Voice network design and optimization.
11-13 Jan. The OSI reference model and network architecture.
16-18 Jan. X25 and packet switching networks.
16-18 Jan. Achieving high levels of computing.
23-25 Jan. IBM's systems network architecture.
23-25 Jan. Advanced data communications.
25-27 Jan. Data base structure and access.

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17-19 Jan. First International Exhibition and Conference on Open Systems Interconnection at the Karlsruhe Messe.

Details from **Messe & Kongreß GmbH • Rotebühlstraße 83 • D-7000 STUTTGART 1 • West Germany • Tel. +49 711 61 80 75.**

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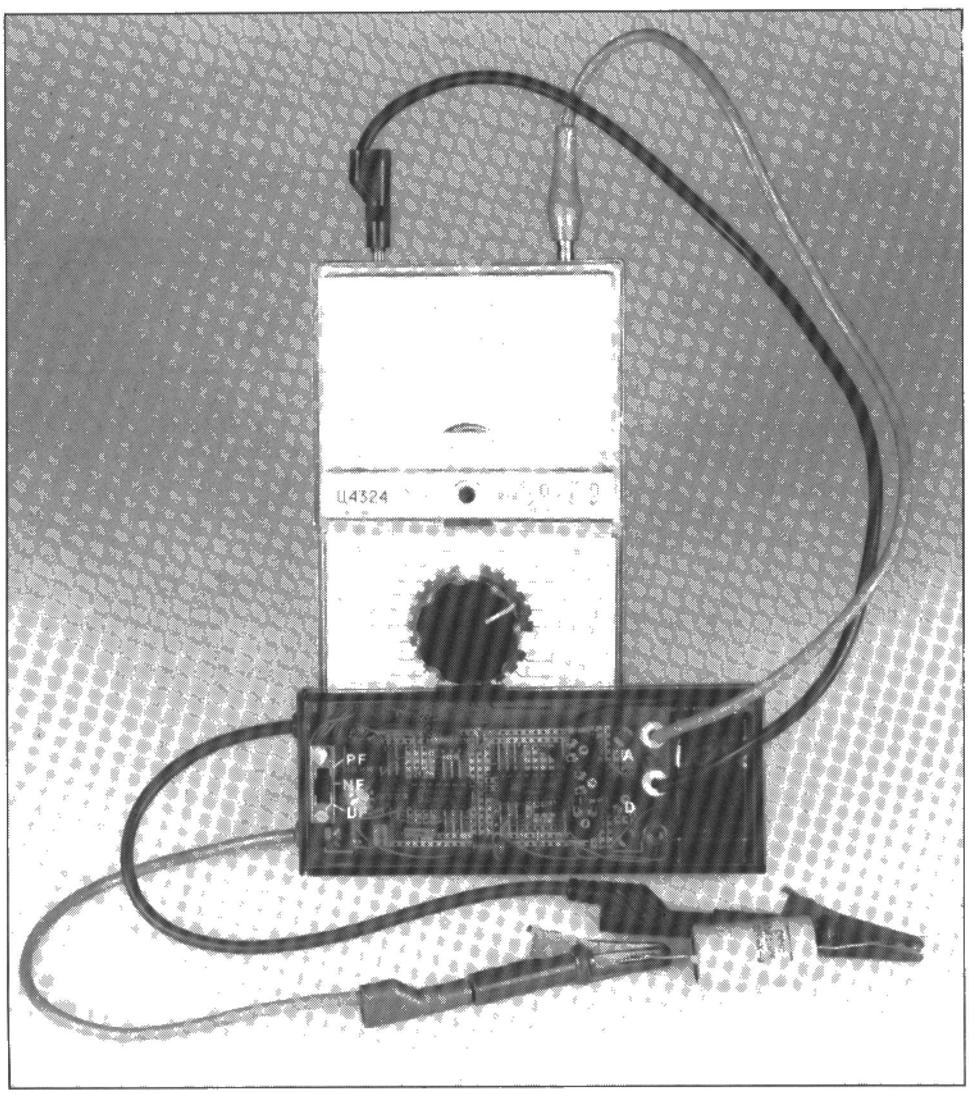
INTERMEDIATE PROJECT

A series of projects for the not-so-experienced constructor. Although each article will describe in detail the operation, use, construction and, where relevant, the underlying theory of the project, constructors will, none the less, require an elementary understanding and knowledge of electronic engineering. Each project in the series will be based on inexpensive and commonly available components.

1. Low-budget capacitance meter

We kick off the series with an add-on unit that turns your analogue or digital multimeter into a capacitance meter with a range of 1 pF to 20 μF.

From a point of view of measuring techniques, capacitors are strange components. An ohmmeter, for instance, can only be used for determining whether or not a small capacitor (that is, one having a relatively low capacitance) forms a complete short-circuit or not — no indication whatsoever is available on the actual value of the capacitor under test (indeed, you may just as well be holding two terminals with no dielectric material in between!). The only, very limited, use of the ohmmeter with capacitors is found with relatively large (electrolytic) types, whose charge and discharge behaviour gives at least a good/faulty indication. Moreover, mechanical defects in electrolytic capacitors are usually immediately apparent at the outside of the device. Determining the value with an ohmmeter, however, is sheer guesswork.



The only useful test for most types of capacitor is simply to check its capacitance against the value printed on it. A good/faulty check is not then not required. Unfortunately. the value is often difficult to deduce from what is printed on the capacitor. What is the meaning behind those coloured bars on the capacitor? What do indications such as n12 or 104 mean?

To prevent an incorrect capacitor being fitted in a circuit under construction, it is essential that its value is measured with some accuracy. This can be done with the capacitance meter described here, whose read-out function is provided by a digital or analogue multimeter. The capacitance meter is, therefore, an add-on measuring extension for the multimeter you very likely already possess.

The overall cost of the capacitance meter is low compared with commercially available instruments. Yet, its wide range and accuracy make it a good choice for the not so affluent constructor.

Capacitance-to-voltage conversion

The operating principle of the capacitance meter is the conversion of capacitance (C) to voltage (V). This function is carried out mainly by MMV_1 (MMV=monostable multivibrator) shown in the circuit diagram of Fig. 1. MMV_1 is triggered by the positive pulse edges of a rectangular

voltage supplied by the oscillator set up around N_1 and N_2. Output Q of MMV_1 goes logic high following each trigger pulse, and remains high for a period determined by the value of C_x, and the total resistance between pin 2 of MMV_1 (R/C input) and the positive supply voltage.

Since MMV_1 is continuously triggered by the oscillator, output Q carries a rectangular voltage whose duty factor, in a particular range set by S_{1a}, is determined by the value of C_x. Connected to Q of MMV_1, an analogue voltmeter will try to follow the instantaneous amplitude of the rectangular voltage. Due to inertia of the moving coil meter, however, an average value read-out is obtained.

The above principle of operation may be illustrated with an example involving practical numbers. Assuming that MMV_1 output Q is logic high (i.e., at +5 V) during 20% of the pulse period time (duty factor 0.2), an analogue voltmeter will indicate 0.2×5 V=1 V. Doubling the value of C_x results in a doubled duty factor (0.4), so that the meter will indicate 2 V. A capacitance meter with a range to 500 pF may be obtained by arranging a suitable clock frequency for MMV_1, and dimensioning the resistance in series with C_x such that 100 pF results in an average output voltage of 1 V. The choice of the clock frequency will be reverted to.

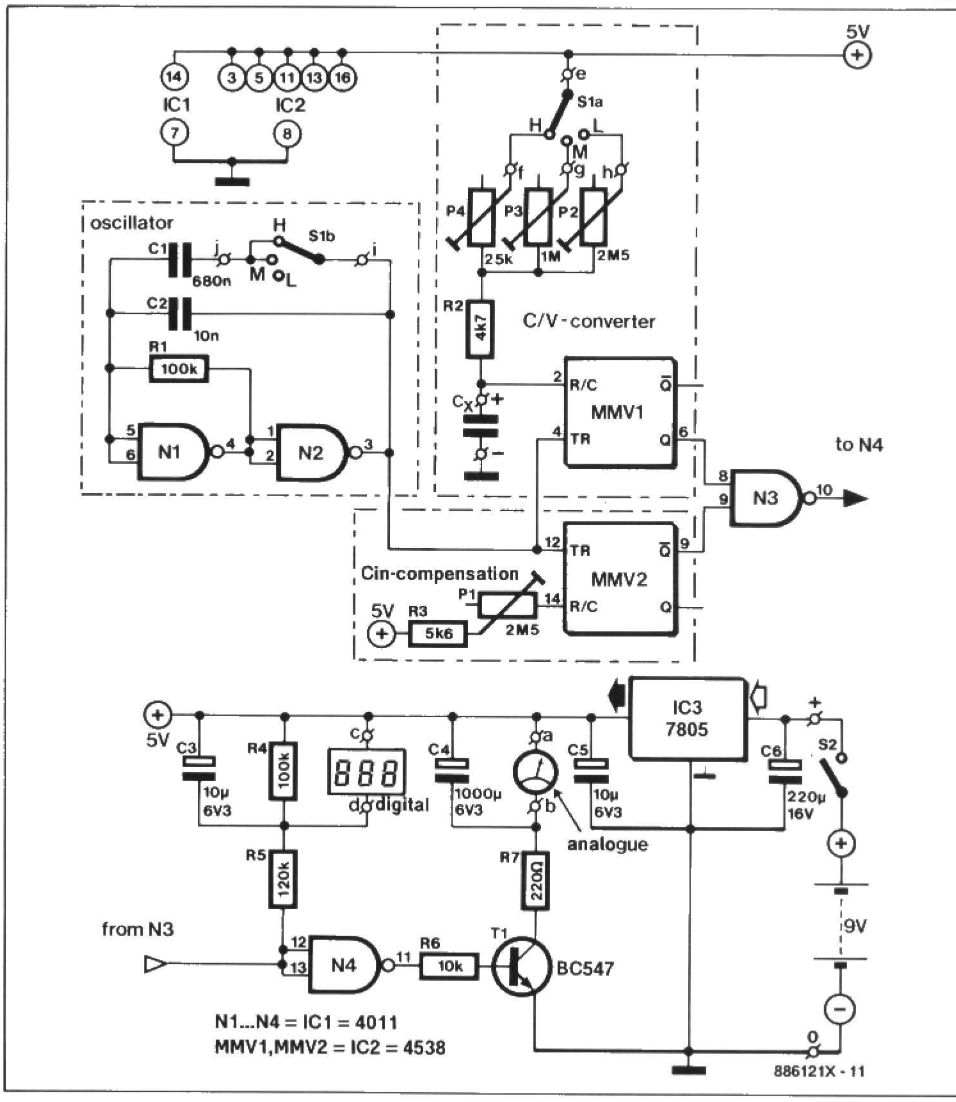


Fig. 1. Circuit diagram of the low-budget capacitance meter.

Pitfalls

A look at the practical circuit diagram of the capacitance meter shows that there is more to the above principle of operation. This is caused mainly by the MMV's internal capacitance, between pin R/C and ground, of about 25 pF, which gives rise to too high readings. The 25 pF capacitor is always there, and should be taken into account when a small value of C_x is measured. Obviously, this offset is particularly troublesome in the lowest capacitance range. Fortunately, a small addition to the MMV circuit, in the form of MMV_2 and N_3, solves this problem quite elegantly.

As can be seen in the circuit diagram, MMV_2 is also triggered by the oscillator, and generates a pulse-train simultaneously with MMV_1. Since MMV_2 has no external capacitor, its monotime is determined by its internal capacitance and the value of series-connected resistors R_3-P_1. The signal at output $\overline{Q}$ (=inverted Q signal) of MMV_2 is subtracted from that at output Q of MMV_1 with the aid of a NAND gate, N_3. As illustrated in the combined timing diagram of Fig. 2, the result is pulse-width reduction of the output signal, or, in other words, a 25 pF offset compensation. The upper line in Fig. 2 shows the oscillator signal applied to both MMVs. As a result of these trigger pulses, output Q of MMV_1 remains high for a duration determined by the value of C_x and the internal capacitance. The $\overline{Q}$ output of MMV_2, however, is low for a duration determined by the internal capacitance. The output of a 2-input NAND (=not AND) gate goes low only when the input signals are logic high simultaneously. In the present circuit, this means that the output of N_3 is low only when $Q(MMV_1)=1$ AND $\overline{Q}(MMV_2)=1$ (boolean equation with the fourth timing diagram in Fig. 2). The pulsewidth of the signal supplied by N_3 is the difference between the input signals applied — in other words, the internal capacitance of MMV_1 (25 pF) has been compensated.

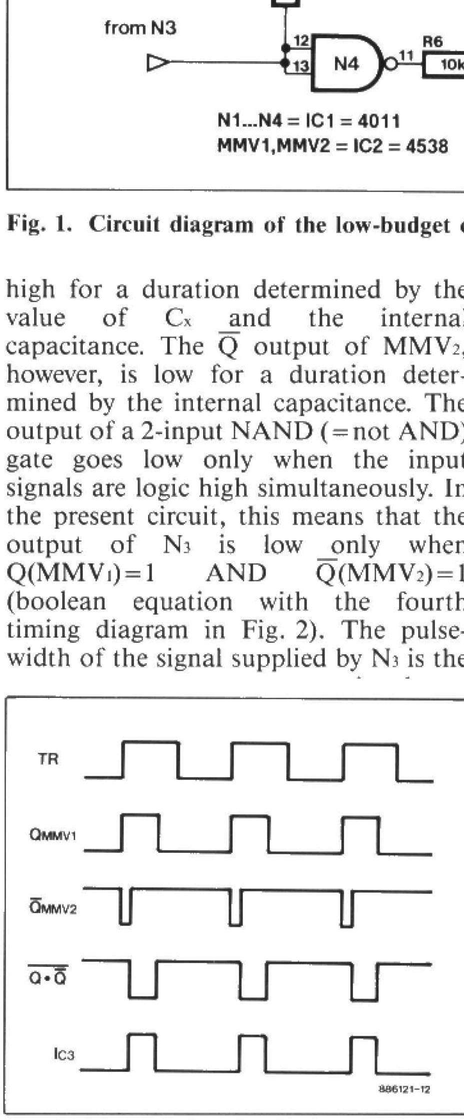


Fig. 2. Timing diagram of the circuit.

Oscillator and range selection

A digital clock oscillator is set up around gates N_1-N_2; positive feedback is provided by C_2 (range L) or C_1+C_2 (ranges M and H). The frequency of oscillation is determined by the selected capacitance and the value of R_1.

Range selection in the oscillator is vital because the Type 4538 dual MMV needs a minimum resistance in the R-C timing network of 5 kΩ. Assuming a preset value of 2.5 MΩ for the 1 nF range of the capacitance meter, it follows that a 250 kΩ preset would be appropriate for the 100 nF range, and a 250 Ω preset for the 10 µF range. The latter resistance value is below the minimum specification for the 4538. For relatively large values of C_x, this means that the oscillator frequency has to be lowered to prevent the signal at output Q of MMV_1 becoming longer than the trigger signal. This can be explained with reference to Fig. 2. Since MMV_1 is triggered on the rising edge of the oscillator signal, the

maximum length of its output signal, Q, equals that of one period of the clock signal (when this is the case, the average output voltage is simply maximum at 5 V). By considerably increasing the period of the oscillator signal (i.e., lowering the oscillator frequency by range switching), the point where the oscillator signal 'overtakes' the Q signal is reached much later, so that a larger value of C_x can be connected with a virtually unchanged series resistance.

Summarizing the above, lowering of the oscillator frequency obviates to a large extent changing the resistance in series with the capacitor.

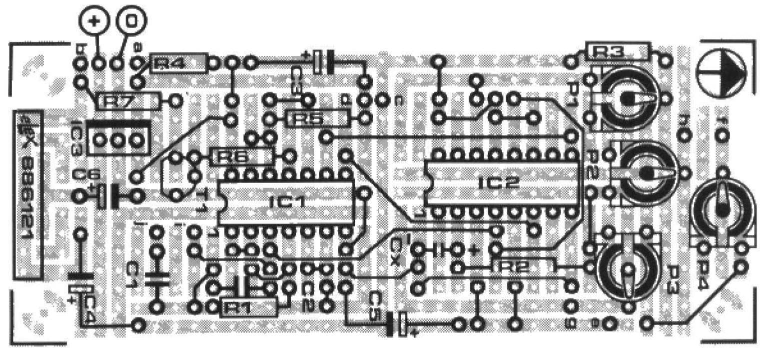


Fig. 3. Showing how the components are mounted on universal prototyping board size-1 (UPB-s1).

Meter drive circuit

Analogue (moving-coil) multimeters generally have a lower input impedance than digital ones. The capacitance meter module is equally suitable for both types of instrument. The output pulses of N_3 are buffered in analogue meter driver N_4-T_2. The inverting function of NAND N_3 is counteracted by the meters being connected to the positive supply line of the capacitance meter circuit. Shunt capacitors C_3 and C_4 are connected across the meters to ensure that the average voltage is built up even at the low pulse frequency of about 10 Hz (S_1 set to position H or M).

In contrast to digital multimeters, analogue meters do not have a standardized input impedance, making it necessary to use different principles for driving each type. To make the drive circuit virtually independent of meter input resistance, the analogue meter is current-driven, while the digital meter is voltage-driven. In general, the series resistance of an ammeter is low relative to the value of R_7. In practice, R_7 is dimensioned such that the multimeter can be set to the 10 mA range. For the capacitance meter, this means that the first range is 10 pF to 1 nF, the second 1 nF to 100 nF, and the third 100 nF to 10 μF. Capacitors between 1 pF and 10 pF can be measured with the multimeter set to the 1 mA range, and capacitors greater than 10 μF with the meter set to the 100 mA range (the maximum output current of the capacitance meter is 20 mA).

The digital meter is voltage-driven, taking the commonly used ranges 200 mV, 2 V, 20 V, etc. into account. Potential divider R_4-R_5 is dimensioned such that the average voltage supplied by N_3 is just higher than 2 V (remember that the maximum voltage difference between pin 10 of IC_3 and the positive supply line is 5 V). The digital multimeter is conveniently set to the 2 V range, so that its overflow indication is meaningful for the capacitance meter also. The available ranges of the capacitance meter are 10 pF to 2 nF (L), 1 nF to 200 nF (M), and 100 nF to 20 μF (H). As with the analogue meter, capacitors smaller than 10 pF can be measured in the next lower multimeter range of 200 mV (this is done automati-

Table 1.

Capacitance	Range	Digital	Analogue
2.2 pF	L	2.2 mV	0.022 mA
12 pF	L	12 mV	0.12 mA
100 pF	L	100 mV	1 mA
220 pF	L	220 mV	2.2 mA
1 nF	L	1 V	10 mA
3.3 nF	M	33 mV	0.33 mA
27 nF	M	270 mV	2.7 mA
100 nF	M	1 V	10 mA
150 nF	H	15 mV	0.15 mA
3.3 μF	H	0.33 V	3.3 mA
20 μF	H	2 V	20 mA

Parts list

Resistors (±5%):
R_1;R_4 = 100K
R_2 = 4K7
R_3 = 5K6
R_5 = 120K
R_6 = 10K
R_7 = 220R
P_1;P_2 = 2M5 preset for horizontal mounting
P_3 = 1M0 preset for horizontal mounting
P_4 = 25K preset for horizontal mounting

Capacitors:
Note: Working voltage, when specified, is minimum
C_1 = 680n
C_2 = 10n
C_3;C_5 = 10μ; 6V3
C_4 = 1000μ; 6V3
C_6 = 220μF; 16 V; radial

A range of polystyrene, styroflex and MKT capacitors is available from Siemens distributor ElectroValue Limited • 28 St Judes Road • Englefield Green • Egham • Surrey TW20 0HB. Telephone: (0784) 33603. Telex: 264475. Fax: (0784) 35216. Northern branch: 680 Burnage Lane • Manchester M19 1NA. Telephone: (061 432) 4945.

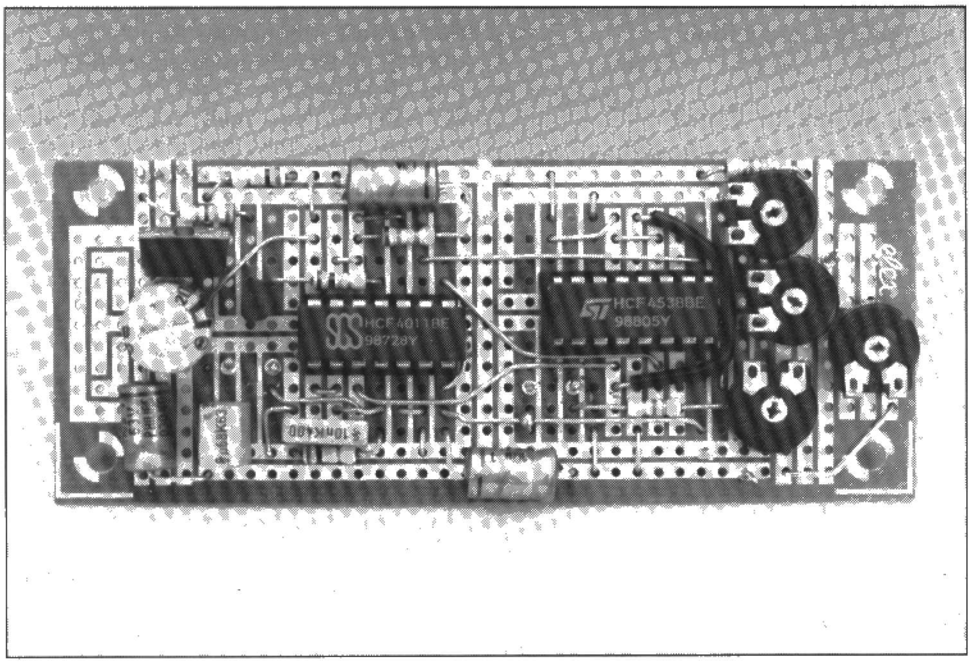
Semiconductors:
T_1 = BC547B
IC_1 = 4011
IC_2 = 4538
IC_3 = 7805

Miscellaneous:
S_1 = two-pole, 3-way rotary or slide switch.
S_2 = miniature on/off switch.
9 V PP3 battery with clip-on leads.
Terminal posts for Cx and meter.
PCB Type UPB-s1 (see Readers Services page in this issue).
ABS enclosure: e.g. Heddic Type 222.

cally by an auto-ranging digital multimeter).
The examples listed in Table 1 help to avoid misinterpretation of the measured capacitor value because of the position of the decimimal point.

Power supply

The final accuracy of the capacitance meter is determined to a large extent by the stability of the supply voltage. The requirements posed in this respect by the clock oscillator do not permit the use of a mains adaptor or battery. The supply voltage for the circuit is, therefore, provided by a three-terminal fixed voltage regulator Type 7805 (IC_3). In spite of the low current consumption of the cir-



Populated printed circuit board.

cuit, the use of an 78L05 is not recommended because its output load regulation is inadequate for this application.

Construction

The capacitance meter add-on unit is built on universal prototyping board 'size 1' (UPB-s1). This 40×100 mm board, which is the smallest in a series of three, is available ready-made through *Elektor Electronics*' Readers Services. Hole spacing is standardized at 0.1 in (2.54 mm), so that virtually any component that will be used in this series of articles, and, of course, in designs and experiments of your own, can be fitted without problems. The board is reusable provided the components are removed with care with the aid of desoldering braid.

The suggested component mounting plan of the capacitance meter is shown in Fig. 3. The board is fairly densely populated, and you are, therefore, well advised to fit the wire links first (use insulated wire). Note that there are a number of very short links connecting adjacent holes — these links may, of course, be made from bare wire. Use soldering terminals for the connections to the meter, the capacitor under test and the battery. Next, fit the resistors, capacitors (mind the polarization of the electrolytic ones!), presets and semiconductors. Integrated circuits must be mounted in sockets. In some cases, it is necessary to bend component terminals with the aid of precision pliers to align them with the holes indicated in Fig. 3. The largest component, C_4, may have to be mounted at the track side of the board, or even direct across the meter terminals.

Now carefully check all connections and component positions against the component mounting plan. The completed board is aligned before it is fitted in an enclosure.

Setting up

The three ranges of the capacitance meter module are first calibrated. Ideally, this is done with the aid of precision capacitors of 1 nF, 100 nF and 10 μF.
The lowest range, 1 nF, should not cause problems thanks to the availability of polystyrene capacitors with a tolerance of 5% or even 2.5%. Most polystyrene capacitors are round, white, with a black ring at one side of the capacitor body, and have relatively thin wires. It is fairly easy to obain twenty or so polystyrene capacitors of values between 100 pF and 10 nF from a salvaged TV chassis. Sometimes referred to as 'styroflex', this type of capacitor is also widely available from electronics retailers.
Unfortunately, polystyrene capacitors with values in the μF range are hard-to-obtain and expensive components. The multilayer MKT type capacitor offers a good alternative, however, and is available in values up to 2.2 μF at a tolerance of 5% or 2.5%. These capacitors, which are housed in a blue, insulated case, are improved versions of the well-known grey MKM/MKC types characterized by the terminals being soldered to the partly metallized capacitor body.

In the following description of the alignment, current readings (mA) and voltage readings (V; mV) refer to the use of an analogue and digital multimeter respectively.
Connect the 1 nF calibration capacitor, C_x, to the meter, which is set to the 10 mA range (analogue meter) or the 2 V range (DMM). Switch S_1 to range L, apply power, and adjust P_2 until a reading of 10 mA or 1 V is obtained. Remove C_x, switch the meter to the next lower range (1 mA or 200 mV), and adjust P_1 for a reading of 0.01 mA or 1 mV. This concludes the adjustment of compensation preset P_1. Connect the test capacitor again, and re-adjust P_2 as outlined above.
The alignment procedure for range M is similar to that for L. Use a 100 nF test capacitor, and adjust P_3.
Adjustment of the high (H) range is best done with the aid of a 2.2 μF MKT capacitor. P_4 is adjusted until the meter reads 2.2 mA (analogue) or 0.22 V (digital).

Final remarks

The above adjustment procedure is based on the assumption that only one type of meter, analogue or digital, is available. A small modification may have to be be made to the circuit when both types of meter are used simultaneously; the analogue meter may give a slightly different read-out that the digital meter owing to tolerance on R_7 and/or R_4-R_5. This difference may be corrected by replacing R_7 with a 500 Ω preset, and calibrating the capacitance meter with the digital read-out.

Next month's Intermediate Project will be a Dark-room Timer.

PRACTICAL FILTER DESIGN (1)

There are still many electronics constructors who are not fully au fait with the operation and calculation of filters. This often results in not always fully correct standard solutions and difficulties when it comes to tracing faults. This new series of articles will attempt to explain the operation of the most frequently encountered types of filter and to make the design of them accessible to everyone.

It is hard to think of any piece of electronic equipment, be it audio, HF, radar, television, or computing that does not contain some kind of filter.
Filters, also called networks, consist essentially of a number of impedances connected together to form a system the behaviour of which depends on the values of the resistances, capacitances, and inductances from which they are made up.
Networks may be classified according to their configuration: T, π, L, ladder or lattice, some of which are shown diagrammatically in Fig. 1.

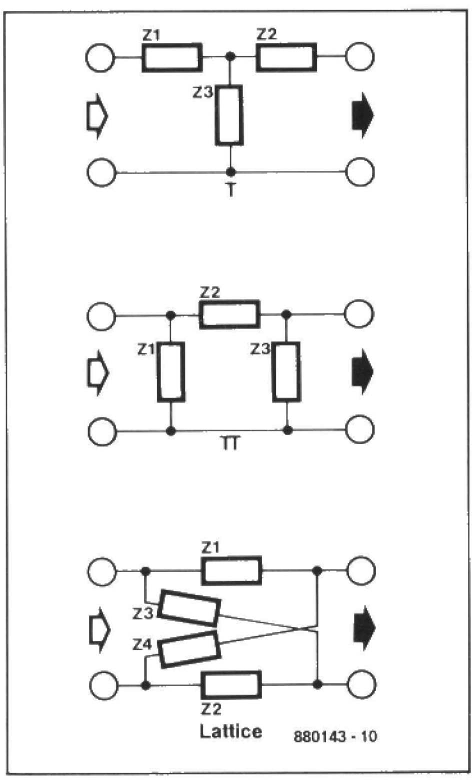


Fig. 1. Diagrams of some basic filter.

They may also be categorized as **passive** (*LC, LR, RC*, or *LCR* filters, strip lines or ceramic resonators) or **active**, in which a device, normally an opamp, plays an active role.
These categories are based on physical parameters, however, whereas we are normally more interested in the way a filter functions. In this series, all networks will be classified according to their mode of operation.

Basic types of filter

There are five basic types of filter, whose pass-bands are shown in Fig. 2.

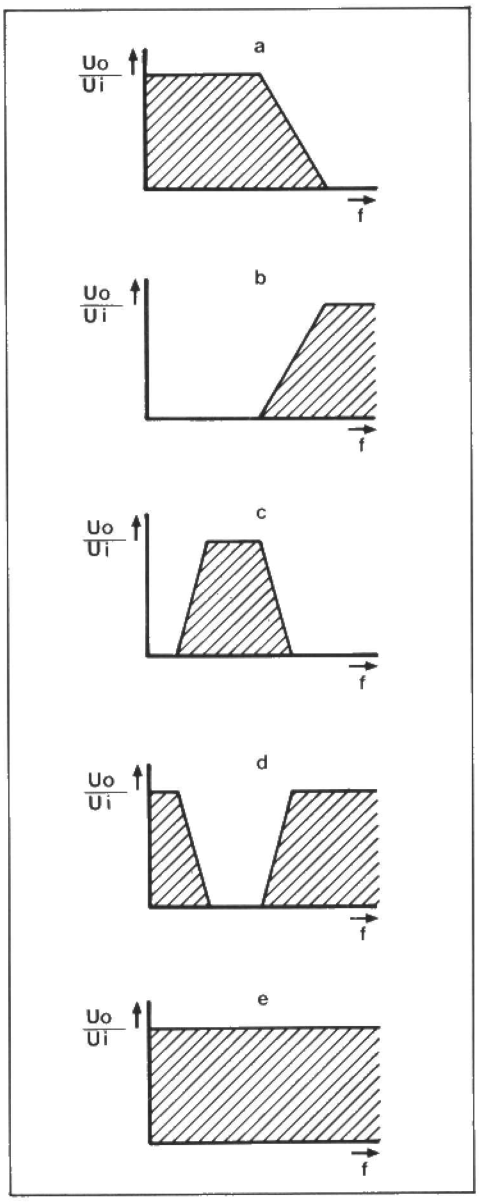


Fig. 2. Pass-bands of the five basic types of filter.

1. **Low-pass**, which passes all signals from d.c. to a certain frequency called the **cut-off** frequency. Above that frequency, all signals are attenuated or suppressed altogether.
2. **High-pass**, in which all signals below a given frequency, again called cut-off frequency, are attenuated or suppressed.
3. **Band-pass**, which passes all signals between two given frequencies, called the lower and higher cut-off frequency respectively. This is the most commonly used filter in electronic engineering.
4. **Band-stop**, which attenuates or suppresses all signals between two given frequencies. Outside those frequencies, all signals are passed.
5. **All-pass**, which passes all signals of whatever frequency, but introduces a phase shift that is a function of the network parameters. Strictly speaking, this is, therefore, not a filter in the true sense of the word.

Except for the all-pass type, all filters may be calculated from the parameters of a low-pass network as will be seen later in the series.

The ideal filter

An ideal filter is a network that passes all signals between two frequencies without altering them in any way and suppresses all others completely. The **skirt** of the pass-band of such a filter is a vertical line—see Fig. 3.

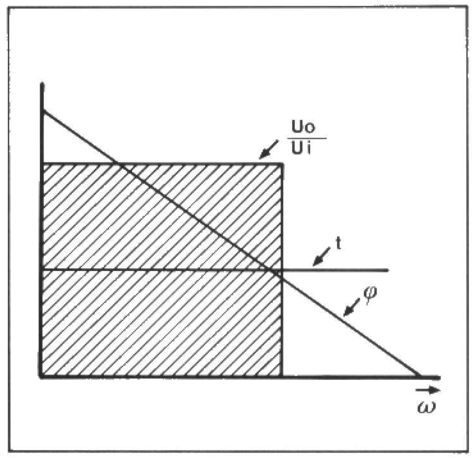


Fig. 3. Pass-band of an ideal filter.

An ideal filter will introduce a time delay between its input and output that is constant for all frequencies—this is shown by the horizontal line in Fig. 3.
From these two (straight) lines, it follows that the ideal phase shift $\emptyset$, is also a straight line.
The time delay, t, at an angular velocity, $\omega = 2\pi f$, of frequency f is derived from the phase shift at every frequency:

$$t = \emptyset / f$$

in which $\emptyset$ is the phase shift in degrees, or

$$t = \beta / \omega$$

in which β is the phase shift in radians. Note that the frequency axis in Fig. 3 is linear; when this is shown, as is usual, logarithmically, the phase characteristic will, of course, look quite different.
The ideal filter can not be realized, so that practical network characteristics are not the straight lines shown in Fig. 3. Also, the time delay in a practical filter does not remain the same for each frequency. The deviations from the ideal characteristic curves have an important bearing on the step and pulse behaviour of the network.

Some network theory

Figure 4 shows the general representation of a terminated filter. The voltage source at the input has an internal resistance R_i, while the output termination consists of resistance R_b.
The two resistances have an important bearing on the functioning of the filter. If buffers are used at the input and output of the filter, however, these resistances no longer affect the operation of the network. Their value must be known when the filter is being designed.

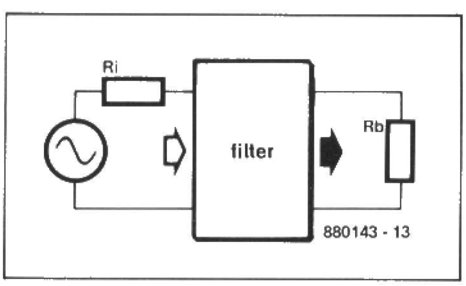


Fig. 4. General representation of a terminated filter.

For example, in the case of a loudspeaker filter, R_i will be virtually zero and R_b will have a value of, say, 6 Ω. In the case of a high-frequency filter, both resistances may have a value of 60 Ω.
These examples show that the design of these networks must be approached from different angles.
The **transfer function** (attenuation vs frequency characteristic) of a filter may be expressed as a vulgar fraction of two complex quantities. For example, the transfer function of the simple filter in Fig. 5 is:

$$T(j\omega) = 1/\{(j\omega)^3 + 2(j\omega)^2 + 2(j\omega) + 1\}$$

Since the denominator consists of a 3rd order equation, the filter is said to be a 3rd order network. The roots of the

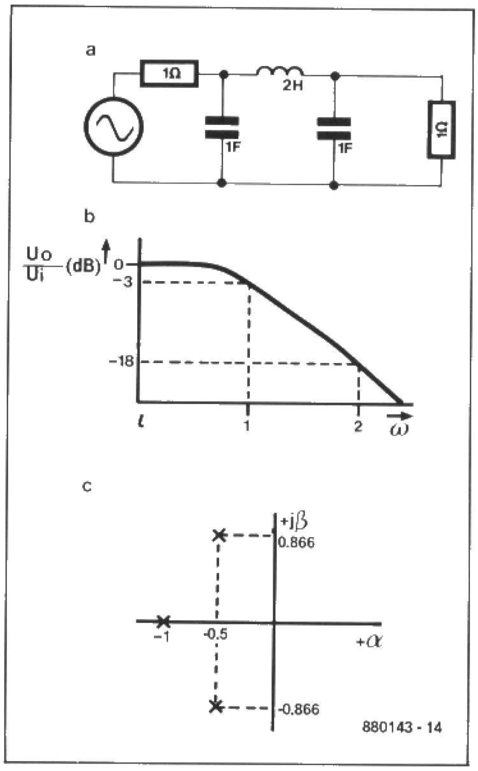
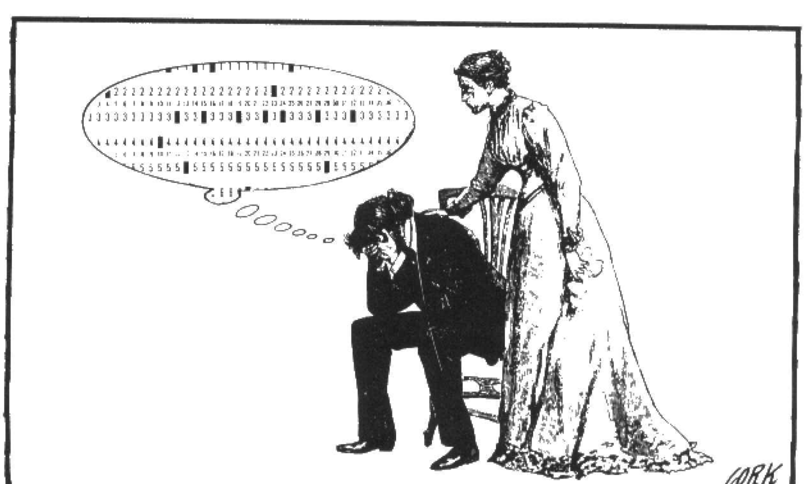


Fig. 5. A basic filter (see text).

denominator are called the poles, and those of the numerator the zeros, of the transfer function. The poles and zeros determine the behaviour of the network. Once they are known, the function of the filter is known and the values of the constituent components can be calculated for any given application.
The complex roots of numerator and denominator may be represented in the complex plane by noughts (zeros) and crosses (poles).
The position of the noughts and crosses in the complex plane determines the stability and practicability of the filter. It is interesting to note that normally the poles and zeros are conjugate pairs. Only poles and zeros that lie on the real axes can exist on their own. Also, poles may lie only to the left of the y coordinate.
The slope of an n-th order filter is, in general nx6 dB per octave. This is, however, only a guideline and depends on the type of filter.
Similarly, the phase shift at the cut-off frequency is, generally speaking, nx45°, but this may be quite different in some types of filter.
Modern **network theory** has produced a number of standard filters, each with its own specific parameters, e.g., Chebishev and Bessel. Since with higher-order transfer functions it becomes tedious to calculate the poles and zeros of a given filter, use may be made of standard tables that give the values for a number of filters.

Further in the series...

In this series, we will deal with a number of filter topologies, passive as well as active, and various filter types. In all cases, the most important characteristics will be given, as will tables for the poles and component values for the various networks.
For passive filters, values of source impedances will be given that are either equal to the output terminating impedance or zero. This will enable a.f. as well as h.f. constructors to profit from the series.
All calculations will be based on a low-pass filter, since from this all other types may be derived. In many cases, worked examples will be used to illustrate the text.
All characteristic curves used in the series have been calculated with the aid of a network analysis program to ensure the highest possible accuracy. In many instances, these characteristics will give sufficient information for the design of a filter for a particular purpose. ♦



IMPROVING AUTOMOTIVE WIRING SYSTEMS

by Alan Baker, BSc(Eng), ACGI, CEng, FIMechE

One of the most outstanding aspects of automotive progress in the post-World War II era has been the proliferation of electrical services. Pre-1939 cars had electric starting, lighting, screen wiping, horns and semaphore-type turn indicators but little more, unless one includes a handful of such developments as Auburn's electric raise-and-lower system for the hood of a convertible. Innovative but, at that time, not adequately reliable.

After the war, though, came a succession of electrically actuated ancillaries aimed at enhancing safety, comfort or convenience. Stop, fog and spot lights, heating/ventilation fans, cigarette lighters, screen washers, rear-window heating and (with the advent of the hatchback) rear wash/wipe, headlamp wash/wipe, central door locking and powered windows, in-car entertainment (as it has come to be called) and the power sourcing for the growing electronics content — ignition, on-board computer, cruise control, engine and transmission management, anti-lock brakes and anti-wheelspin devices.

And there is more to come as four-wheel drive and steering gain favour and suspension is improved through automatic damper-rate variation or, in the longer term, fully active systems.

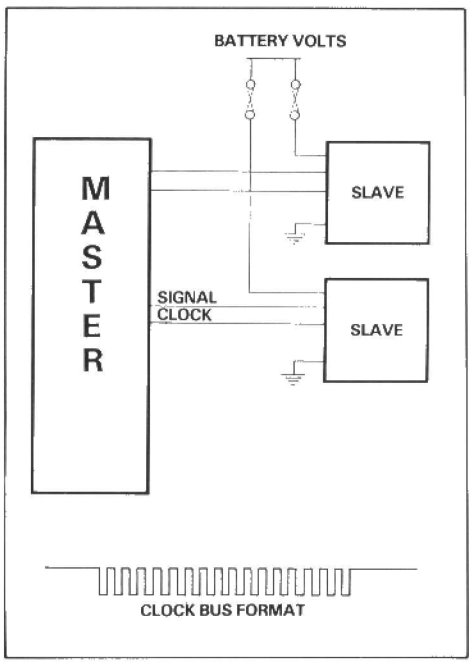
Small wonder, then, that conventional electric harnesses have been becoming ever more complex, bulky and costly. For a well equipped car the loom may now involve thousands of wires and weigh many kilograms, as well as impose significant installation and maintenance problems. Some easing of the situation was gained from reducing individual insulation thicknesses, but this was just a palliative — the cure demanded a more drastic approach.

University advice

That approach, now called multiplexing, has existed as a concept for some years but it has raised many practical difficulties that have only recently been overcome. In ideal multiplexing, every service on the vehicle would be supplied with electricity via a sort of ring-main—as in a building—with local intelligence or logic to decide what should be on and what off.

Such a scheme would have a major snag, though. It would have to be entirely of heavyweight 60 A cable to carry the current. A major compromise was clearly essential.

One of Britain's major electrical suppliers, the Volex Group, latched on to the possibilities of multiplexing some eight years ago and soon became aware of this and other associated problems. Volex's wiring specialists reckoned that the computer might help them towards a solution, so they consulted Professor Michael Hampshire, then head of the Department of Electrical and Electronic Engineering at nearby Salford University.



Schematic layout of Salplex multiplexing system, based on a master unit and the appropriate number of slave units.

This is not the place for a detailed evaluation of the consequent work at Salford, but its end-product was a rational computer-based system for converting an automotive customer's wiring drawings into a viable multiplexing scheme based on a plurality of feed cables rather than the single conductor of the idealized ring-main.

The manufacture of hardware of this innovative type was outside Volex's operational ambit. To meet the situation, therefore, a new company, Salplex Ltd, was formed jointly with the General Electric Company of England, and a new factory was built for it at Rugeley. The time since the formation of Salplex in 1980 has been devoted to evolving fully practicable automotive systems.

Levels of multiplexing

The main technical problems had all been solved by 1984, since when the company has been refining its designs and developing the appropriate production techniques in readiness for the rush that looks about to start. It became apparent relatively early that any attempt to evolve a panacea multiplex system was doomed to failure since it would be over-sophisticated for some duties and too primitive for others.

One organization to recognize this fact was the United States Society of Automotive Engineers (SAE) which, in consultation with the country's auto manufacturers, established three levels of multiplexing.

Salplex's lowest level, corresponding to the SAE's Class A, is that suitable for vehicle body electrical systems where the requirement is for simple on/off switching of each service. Class B caters for shared information and communication, message sending and handling.

Class C is a higher tech and often higher speed (and consequently much more expensive) system including in car diagnostics, anti-lock braking, engine management and the control of automatic transmission.

Integrated multiplexing for a car therefore has to be a combination of Classes A and B. The two elements cannot be discrete, though, but have to have an interface since, in some areas, communication between the two types of function is essential. Salplex has developed a combined system of this kind, carrying the Series 4000 designation.

The system handles not only the communications function but also the interrelated switching one as, for example, when headlamps have to be controlled by the ignition switch, the high/low-beam switch and the headlamp-flash switch. This functionality, as it is called, is programmed into the master unit and is not dependent on complex switches or

relay logic.

A working system

The essence of multiplexing is time division, which ensures that each service gets its share of the conductor (known as a bus) without interference from the others using it. Several rechniques have been evolved for time division and that chosen by Salplex for the Series 4000 is known as time-slot assignment, based on the maximum acceptable time delay between an input event (a switch closing) and the related output event (a lamp lighting). This time interval is divided into a number of time slots, each of which is available for moving the data or commands allocated specifically to it.

In brief, the Series 4000 is based on a central master module and a number of slave modules distributed about the vehicle. While the master module is responsible for power and signal distribution and all logic functions and timing, the slave modules service the complement of loads and switches either directly or through sub-harnessing.

Many of the world's major motor manufacturers are currently evaluating the Salplex system, along with comparable equipment from the handful of other companies that have succeeded in negotiating the many obstacles on the multiplex road. In the meantime, the company continues its research and development in collaboration with its parent firms, being determined to build on its sound foundations and to be in a position to supply proven and practicable hardware when the multiplexing bandwagon begins to roll.

Salplex Ltd • 7-8 Riverside Industrial Estate • Rugeley WS15 2YR.

NEWS

Satellite communications

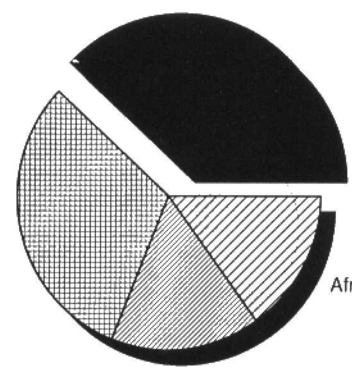
Since INTELSAT 1 ("Early Bird") was launched more than 23 years ago, dozens of commercial communications satellites have gone into orbit—overcrowding the C-band (4-6 GHz) and forcing migration to the Ku-band (11-14 GHz), which is now also becoming overcrowded. Next in line is the Ka-band (20-30GHz).

Satellite Communications in Developing Countries, a report from Frost & Sullivan, estimates that, on average, 20 commercial satellites will be launched worldwide each year through 1995. About four fifths of these will be for communications and about 40% of them will be for use by developing countries.

Over the past 20 years, satellites have become more complex, more powerful, and considerably larger. Early Bird was 1.37 m high, whereas the latest INTELSAT VI, due for launch later this year, will stand almost 12 m high and will be several times larger than a private car.

Large, powerful satellites make possible smaller, less complex, and thus cheaper, earth stations. The report estimates that at present just over 3,000 earth stations with antenna diameters of less than five metres are installed in developing countries, but that by 1992 that number will have grown to almost 35,000.

SHARE BY REGION OF TOTAL EARTH STATION MARKET FOR DEVELOPING COUNTRIES - 1992



SOURCE: Frost & Sullivan, Inc. Report #W1036

1992 Total Value $227.12 Million

The end of morse

Morse code, the radio message system used by ships at sea and thousands of radio amateurs the world over, is to become a thing of the past, at least as far as professional services are concerned. The International Maritime Organization in London has given the go-ahead to the introduction of a more advanced digital replacement. The global maritime distress and safety system will be introduced in 1999. Messages will be handled automatically, mostly by satellite. Any distress signal will be coded to identify the ship automatically.

£15.8 million telex investment

British Telecom is to spend a further £15.8 million to complete the modernization of its inland telex network.

This will bring British Telecom's investment in the telex network to more than £100 million in the past five years and will lead to an all-digital network within three years.

Direct dialling over the UK telex network was introduced in 1958 and to Europe in 1961. Automatic telex is now available to more than 200 countries.

Communications network

A low-cost communications network, designed to perform the functions of multiple direct RS232 links between computers, peripherals and other communications devices, has been developed by Infa Communications of Henly-on-Thames.

The network provides simultaneous links within it, subject to an overall limit of 115,000 bits/s for the rate of transmission of data around the ring.

The system is suitable for small and simple or large and complex sites and is readily expanded (with fibre-optic links between coaxials rings). It is designed for hostile environments, will function reliably at full speed over distances of up to a maximum of 800 m between nodes (without the use of line drivers) and more than one computer may be accessed.

Total Frequency Control

A new company has been launched for the marketing of frequency control products. The new company, named Total Frequency Control Ltd (P.O. Box 1004, Storrington, West Sussex HH20 3YU, Telephone 09066 5513), is unique in its conception and will, for instance, offer custom design of all oscillator products with an emphasis on TCXO and VCXO oscillators.

CALSOD, A LOUDSPEAKER DESIGN PACKAGE

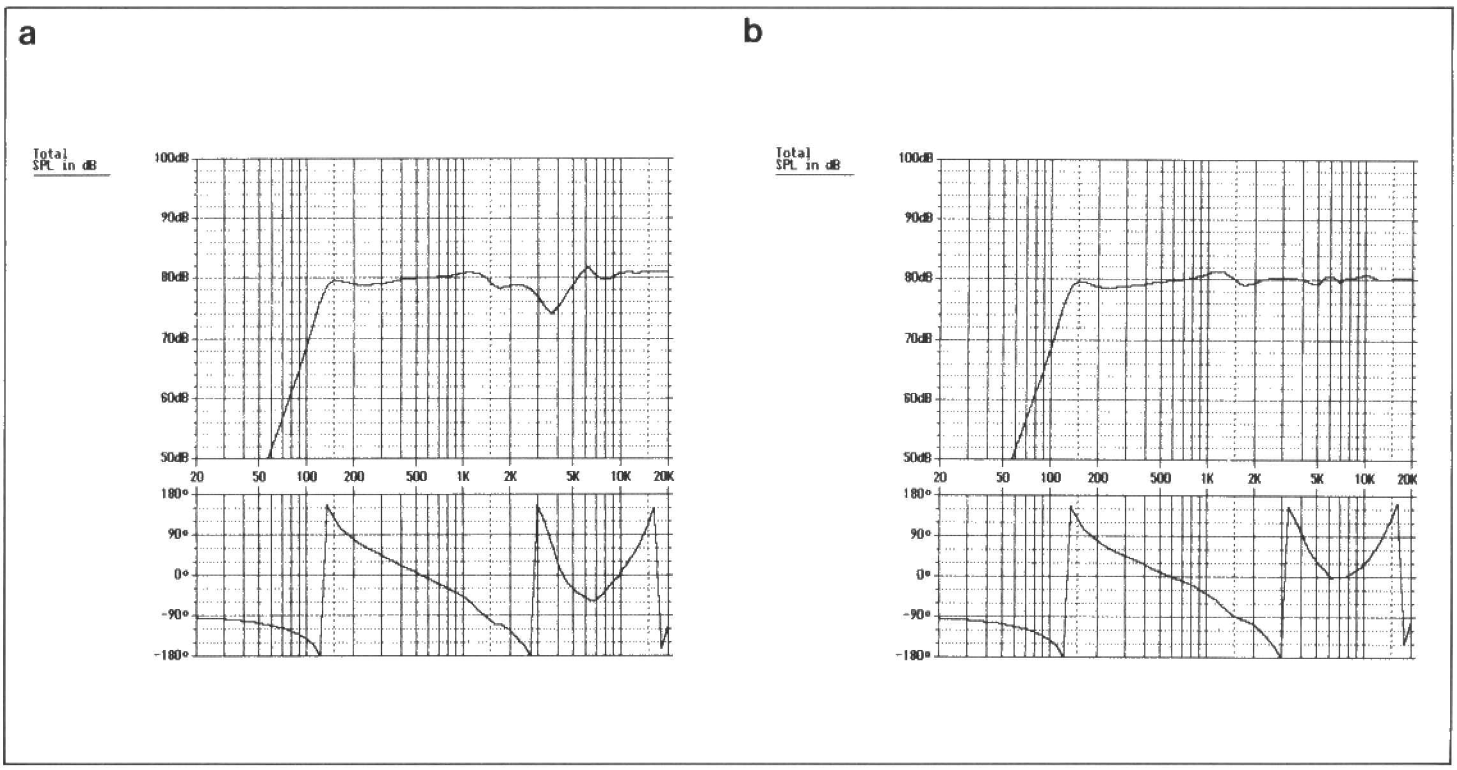
Until recently, computer-aided loudspeaker design and optimizing could only be implemented on mainframes. Fortunately, that has changed, and a new, comprehensive, design package, CALSOD, is now available for PCs as well. This article reviews CALSOD, and reports on its use in a practical test.

Designing a good-quality loudspeaker box invariably requires solid background knowledge, a lot of time, and reliable test equipment. If any one of these three ingredients is lacking, the final design will almost certainly fail to give satisfactory results. Serious designers will no doubt have the relevant equipment and background knowledge, but often lack time to go through the stages of testing and redesigning the box. The design of a multi-way loudspeaker system invariably commences with setting up a theoretical model on the basis of available data on the drive units to be used. Next, a prototype is built to clear the way for practical tests. Measurement results generally deviate widely from those expected on the basis of the calculations. This is so because it is very hard, if not impossible, to include each and every parameter in the calculations. Filter response, impedance, frequency and phase characteristics of the drive units are all fairly simple to determine on their own, but complex calculations in simulation programs are required to predict their combined effect, leading up to the total response of the filter and drive units. Unfortunately, the development and use of such simulation programs is the exclusive domain of leading loudspeaker manufacturers. Not only the software investment, but also the mainframes used for running these programs are well out of reach of individual box designers and small companies. The arrival of CALSOD has changed this radically. Other software packages for loudspeaker design and optimizing, offering a price/performance trade-off at least equal to that of CALSOD, are, to the best of our knowledge, not available.

Computer-aided design

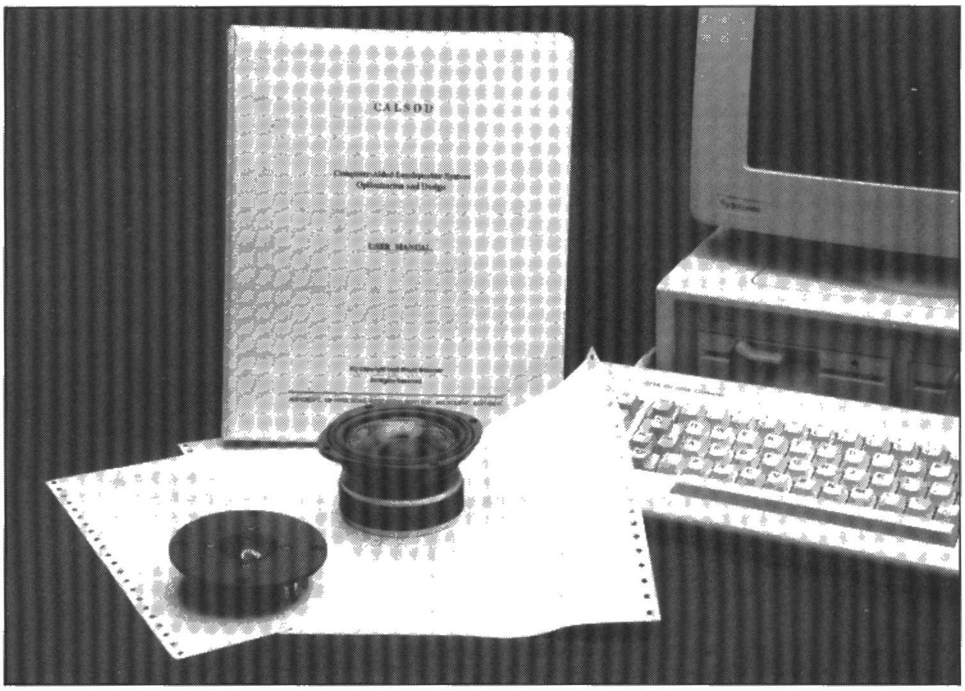
CALSOD stands for Computer-Aided LoudSpeaker Optimizing and Design. Although 'Design' would normally precede 'Optimizing', the acronym covers the function of the package very well. A series of extensive tests with CALSOD has spurred our enthusiasm about the program. The redesign feature of the program was tested on existing loudspeaker systems. Remarkably, CALSOD's computed response was found to correspond exactly with the measured response.

CALSOD is actually a set of subprograms that together offer the possibilty to calculate everything a designer needs to know to achieve optimum results from the available drive units, whose technical characteristics are first entered in the program (impedance, frequency and phase response; Thiele/Small parameters, if available). Obviously, accuracy of the computed results is determined to a large extent by the accuracy of the input data. A number of fairly simple program modules then allow converting the measured curves into a kind of equation used for processing by the program. Examples of available filter modules include one capable of generating a second to fifth-order Butterworth characteristic, one representing the response of a drive unit in a closed box, a bass reflex box, a passive radiator, and so on. Small irregularities in a response curve can be simulated accurately with the aid of so-called 'minimum phase equalizers', which are essentially tuned circuits whose resonance frequency, Q (quality-)



These graphs show the total acoustic output of a two-way loudspeaker system before (a) and after (b) optimizing with CALSOD.

factor, and amplification or attenuation can be specified by the user.
After the curves have been simulated with the aid of modules, these can be 'fitted with' the appropriate filters. All data is put into a text file that looks similar to a netlist for SPICE. The integrated word processor is then used for making a file for each loudspeaker. The file contains the component values, and the way components are connected to nodes in the network. Global values can be entered for filter specifications, e.g., representing an ideal filter terminated in a pure resistance.
Next, the target response curve is specified, e.g., that of a fourth-order Linkwitz filter dimensioned for a cut-off frequency of 5 kHz. The file with all data is then read into the program, after which network analysis is performed. The user is then in a position to study all the relevant parameters: frequency and impedance characteristics of the box, output voltage of the filter, input impedance of the loudspeaker(s) plus filter, and the acoustic output signal of the box plus filter. The target response curve can be projected over the measured response, so that deviations can be assessed before the optimizing process commences. CALSOD changes component values in the filter until the acoustic output signal is a reasonable approximation of the target specification. The user is in a position to state beforehand which components may be redimensioned by the program. All loudspeaker sections are processed in this way to obtain a larger file that contains optimized data for all sections.
The complete system is then ready for analyzing. Individual curves can be displayed separately, as well as the sum signal produced by the loudspeakers, measured at a predefined distance from the box. CALSOD even offers the possibility to indicate vertical and horizontal position of the loudspeakers on the front panel of the box, as well as inter-loudspeaker distance relative to the listening position. This facility allows studying the effect of, say, a 3 cm displacement of the tweeter, or a 10 cm displacement of the listener. Finally, CALSOD is a capable of optimizing the complete system, working effectively towards the realization of the target response.



Practical and with plenty of options

CALSOD is a well-designed and remarkably practical program that will prove invaluable to the designer who knows what he is doing. Evidently, the program is and remains but a tool that works on the basis of the user's experience gathered from previous loudspeaker designs. None the less, this tool greatly simplifies formerly often tedious and time-consuming work. The optimizing procedure can provide really good results, and the options for analysing a complete system are unique. On a less positive note, the program is fairly cumbersome to work with. As in SPICE, changing a single value in the input file is basically simple, but time-consuming. Before a new analysis can be performed, the user must return to the word processor, change the text where appropriate, load the modified file into CALSOD, and restart the analysis. Remarkable in view of the fairly heavy calculation load, the review package of CALSOD did not support the use of a maths co-processor in the PC.

CALSOD may be ordered direct from AudioSoft, 128 Oriel Road, West Heidelberg 3081, Melbourne, Australia. The package costs A$349.00 inclusive of postage and packing.

NEWS

AI adds intelligence to chip design

European Silicon Structures—ES2—of Bracknell has signed a £250,000 contract with the Artificial Intelligence Applications Institute (AIAI), the AI technology group at Edinburgh University.
Initial trials work began last March when AIAI built a prototype intelligent front-end for ES2's existing chip design with their AI tool kit, Knowledge Craft. Following this, the next stage will be to investigate and prototype systems for testing and evaluating circuit designs.
ES2's policy is to encourage the implementation of unique systems solutions on silicon and to bring the benefits of custom silicon technology within the reach of all equipment manufacturers by lowering barriers to its use.

Prime Computer and British Telecom announce co-operative effort

Prime Computer Inc and British Telecom, through its US subsidiary Dialcom Inc, have announced a worldwide co-operative effort to develop, market and support communications systems for electronic messaging and information systems for major enterprises.

GEC/Thorn EMI national cordless telephone service

GEC and Thorn EMI have applied in the name of "Callmaker" for a licence jointly to operate a national cordless telephone service.
The Callmaker Telepoint system will allow members of the public to make outgoing telephone calls over the Public Switched Telephone Network using second-generation cordless handsets. Base stations will be located at strategic points throughout the United Kingdom and when users are within range they will be able to dial anywhere in the world. Paging facilities will be added to enhance the service.

TEST & MEASURING EQUIPMENT

Part 13: Power Supplies (1)

by Julian Nolan

Farnell LT30/1 Power Supply

Farnell are a large and well-established electronics company who, over the years, have gained a good reputation, especially in meeting the instrumentation requirements of the educational sector. Farnell has a wide range of products in its T&M range, from synthesized r.f. signal generators to low-cost oscilloscopes.

The LT30/1 is a dual 0—30 V, 1 A power supply that retails at £230+VAT. The LT30/1 is one of a large range of power supplies that includes such units as the TSV70 which provides 0—70 V at up to 10 A output.

The unit is characterized by its use of twin analogue output meters instead of the more common dual, often quadruple, digital meters that accompany some power supplies. Constant-voltage or constant-current operation is possible, while the output is protected against overloads and short circuits.

Connection to the mains is by a fixed lead. The mains input voltage may be set to 110 V, 130 V, 220 V, or 240 V a.c.

Operating characteristics

Line regulation is good at less than 0.01% output change (constant current or constant voltage) for a ±10% change in mains voltage. Load regulation is also good, with a 0.01% change in output for a zero to maximum change in the load. These specified conditions were matched on the review model. This facility, together with the low temperature coefficient of 0.01% per °C, enables accurate output levels to be set at switch-on, irrespective of load variations or operating time. Initial drift was also low on the review model and should not be significant. None the less, as a safeguard, a separate output switch is provided. This enables the supply to be adjusted in circuit and left in stand-by prior to supplying the load. This arrangement provides good regulation without a warm-up delay.

Ripple and noise do not present any undue problems: they are below 1 mV_{pp} (constant voltage dF=80 kHz) under full-load conditions.

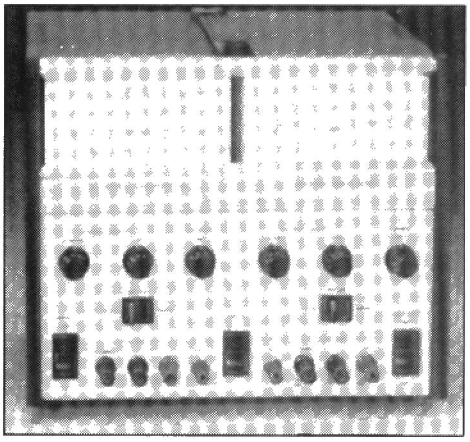


Table 19

TECHNICAL SPECIFICATION

Line voltage: 110 V; 130 V; 220 V; 240 V ±10%
Line regulation: <0.01% of max. output for a ±10% change in mains voltage
Output impedance: <0.1 Ω at 100 kHz
Temperature coefficient: 0.01% per °C (typical)
Transient response: <25 μs for output to recover within 50 mV following a 10% to 100% change in load
Ripple and noise: <1 mV (typical)
Voltage control: coarse and fine controls
Current control: single control only
Protection: against full overload and short circuits
Metering: twin analogue meters (30 V and 1 A f.s.d.)
Meter accuracy: not known
Output terminations: 4 mm terminals
Sensing: remote current sensing only
Other features: output switching; dedicated current source mode
Dimensions: 226×254×249 mm (H×W×D)
Weight: 8.4 kg

The transient response time is also good: the output recovers to within 50 mV in 25 μs following a 10%—100% load change of 1 μs rise time.

The current limit is continuously variable over the full current output range of 1 A: the trip temperature coefficient of 0.02% enables this to be known accurately at all times.

The LT30/1 in use

In use, the LT30/1 scores highly: clear indications are provided of current overload and output current/voltage. The use of analogue instead of digital meters has, of course, a cost advantage and also allows trends such as, for instance, the current drawn to be seen more easily. On the other hand, analogue meters do not offer the resolution of digital meters, although on a power supply this is not really a critical factor. None the less, it would have been useful to have the option of switching the meters, for instance, to have constant-current and constant-voltage metering on a single output rather than the obligatory one meter per output switching arrangement. Both meters can be switched between current and voltage monitoring.

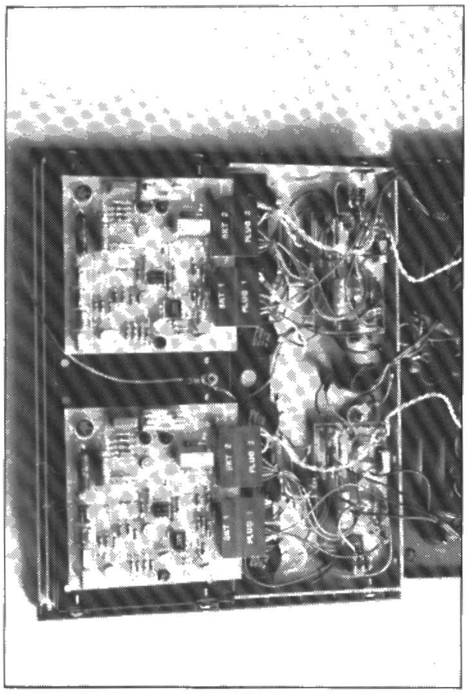
The constant-current facility should find many applications from providing a reference for a DAC to charging NiCd cells, for instance. A current-sense input enables the constant-current output to be set with high accuracy.

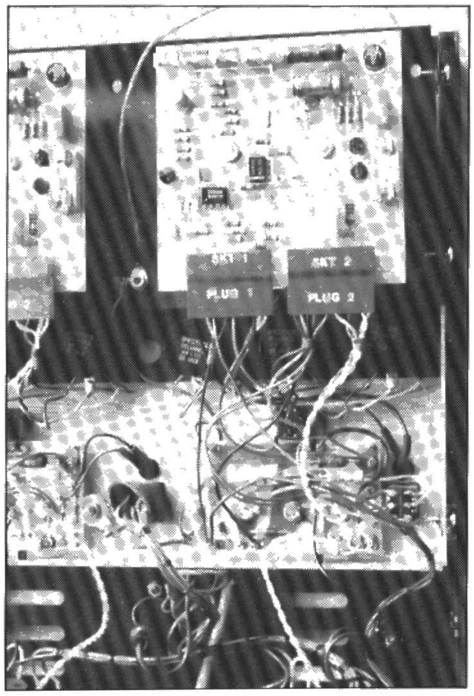
Since voltage sense inputs are not provided, no automatic compensation can be made for the potential drop across the supply leads, although with a 1 A supply this is not of great importance with commonly used leads.

The outputs may be paralleled to increase the maximum output current to 2 A, while a maximum output voltage of 60 V is available if the outputs are connected in series. These arrangements work well, but it would have been useful if an internal switching network instead of the necessary reconfiguration of the output terminals had been provided.

Construction

The external construction is based on a steel chassis and a stove-enamelled steel enclosure. The neat front panel consists largely of aluminium, as does the back panel. Heat sinks are mounted on the





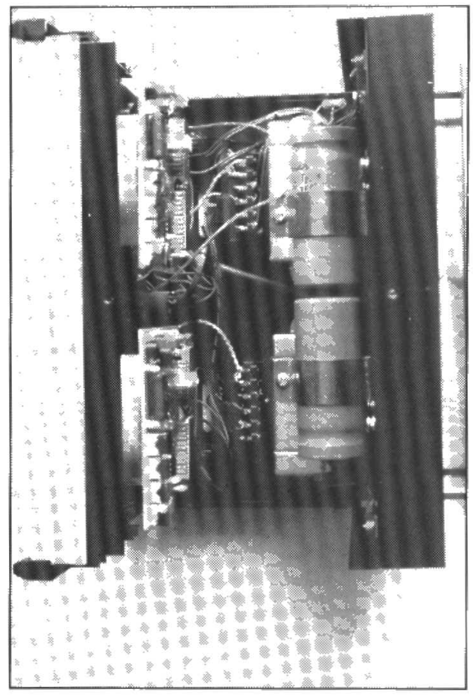


Table 20

	Unsatis-factory	Satis-factory	Good	Very good	Excellent
Voltage control					*
Current control			*		
Regulation				*	
Meter accuracy			*		
Overall accuracy				*	
Output impedance			*		
Internal construction					*
External construction					*
Overall specification				*	
Ease of use				*	
Manual				*	
Additional features				*	

back panel. The construction gives the instrument a justifiably solid appearance.

The internal construction is of the same high standard. The unit consists basically of two single power supplies housed in a single enclosure. Each supply is based on a separate transformer and printed circuit board. Access is good, so servicing should not present undue problems.

Heat dissipation is low even at high output currents.

Overall, the power supply should be able to withstand use in most environments and should not be damaged easily.

Manual

The manual provided with the instrument contains fairly detailed operating instructions, together with a full range of applications. There is also a full circuit description, components list and a circuit diagram.

Conclusion

The analogue meters of the LT30/1 may initially cause concern to some users, but they have advantages over digital types. This small point is, however, offset by the LT30/1's high standard of construction and a range of facilities that are well above average.

The constant-current mode is particularly useful, as are the current-sense inputs where high accuracy is required. Given the accuracy and resolution of the good-quality analogue meters, the absence of remote voltage-sensing should be not too significant.

The high-grade construction should make the instrument appeal to a wide range of users, especially in the educational and business sectors where Farnell already has a good market.

In perspective

At an RRP of £230, the LT30/1 may appear to be overpriced when compared with other power supplies offering a similar specification and quadruple digital meters for, typically, another £20. However, if the dual analogue meters are acceptable, the LT30/1 represents good value. Farnell have earned a good reputation in the test equipment market.

The LT30/1 was supplied by Farnell Instrument Ltd, Sandbeck Way, Wetherby, West Yorkshire LS22 4DH, Telephone (0937) 61961.

Some other PSUs from Farnell

Owing to the large range of power supplies available from Farnell, only a brief outline of specifications can be given.

L series: single (0—30 V at 1 A and 0—30 V at 5 A); and dual (0—30 V at 1 A and 0—30 V at 2 A). Prices from £121+VAT to £282+VAT.

D series: various models from other ranges (mostly L) but with digital meters.

5000 series: a range of low-cost units, including 0—15 V at 1 A and triple output models. Typical RRP around £45+VAT.

E30 series: 0—15 V at 2 A or 0—30 V at 1 A; other versions available. Typical RRP around £110+VAT.

Triple output: various output voltages available at different current ratings; RRP from £114 to £250; some models include digital meters.

A heavy-duty range is also available with 3 kW maximum output; prices up to £2,450.

SCIENCE & TECHNOLOGY

Software without tears

by Dr Hugh Porteous, Department of Mathematical Sciences, Sheffield City Polytechnic

Many firms that are not big enough to employ professional computer systems analysts run into trouble when embarking on the task of programming. A great deal of money is often wasted in this way, but it need not happen if someone on the staff takes a short, home course prepared by academic mathematics departments and a large computer manufacturer in the UK. The course is now available through the Institution of Electrical Engineers.

Most people associate computers and mathematics. For many, mathematics means 'sums', amounting to addition, subtraction, multiplication and division and, because they see computers as big machines that do number calculations with great speed and complete accuracy, they think mathematicians are virtually redundant. Others, more aware of the limitations of computers, still see a role for the mathematician but see the relationship between a mathematician and a computer as that of a master who wishes to perform some task and a servant who does all the dirty work.

And most people who work with computers know that the vast majority of jobs handled are not complicated numerical calculations but more mundane tasks such as keeping records of stock in a warehouse, producing labels of names and addresses for mailing purposes or handling a company's payroll. The level of mathematics required is elementary arithmetic. For example, if I have five boxes of a particular part and I sell one, I have four boxes left. If I then order two more, I have six. Mathematics seems remote and irrelevant.

While people wrote simple programs to deal with simple tasks, all was well. Usually, programs worked and if they did not the author of the program would quickly discover what was wrong and put it right. As programs grew more complicated, the programmers grew with them, gaining more and more skill at circumventing the limitations of the machines they were using and the languages with which they communicated with the machines. Programming had become a 'craft'.

Too complicated

At about this stage things started to go wrong. Tasks tended to become too complicated for a single programmer and attempts were made to patch together the work of several people. Often this worked very well, but sometimes one part of a program reacted on another in a way that none of the programmers could have anticipated and the computer produced incorrect results. Sometimes that would be cured by modifying the program in a suitable way — until, that is, another programmer came along, interpreted the modification as a 'mistake', and put it 'right' again.

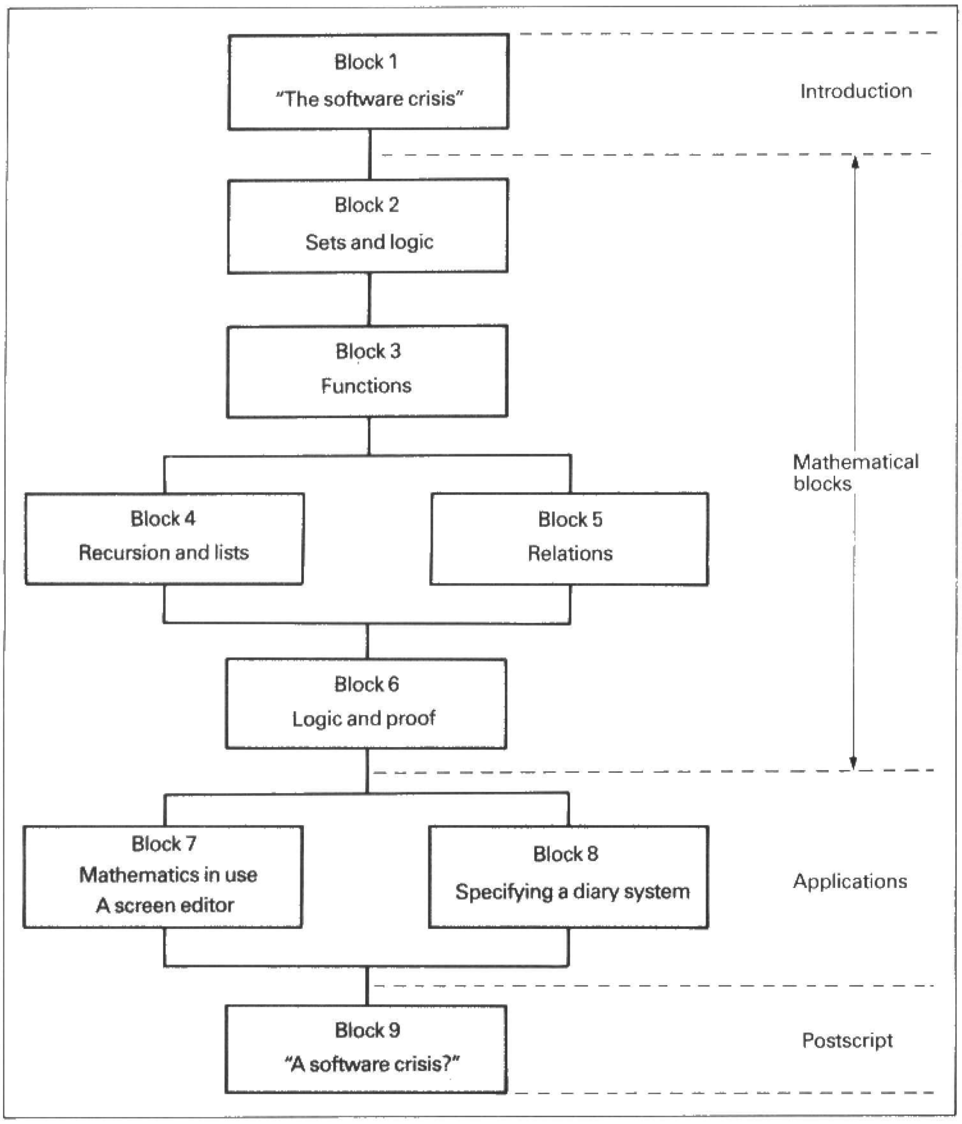
In seeking to solve this problem, the industry has evolved from the craft discipline of programming to the engineering discipline of software engineering. This involves building up programs in a modular function, with each module independently tested to make sure that it performs as required. The final program should have a relatively simple structure so that it is easy to check that it is correct. The result should be error-free software, or at least software where errors can be put right without creating a whole host of new ones. The key to such a strategy is specification. There is no point in writing large numbers of modules for programs if the other members of the team cannot understand what they do. It is important to realise that what matters, once a module has been written, is *what* it does, now *how* it does it. The specification of a program module should declare what inputs the module will accept, the sort of output to be expected and a statement of how the input and output are related. Just how to obtain the output from the input is important to the writer of the module, but may not be so to the user.

Off the shelf

All this has taken us a long way from mathematics. Yet it is not so far. For the analogy with other engineering disciplines is deliberate. If we are designing a new machine we may well construct it with parts 'off the shelf' and they too will be built to a specification. Critical parts will be built to certain sizes, strengths and weights, and it will be not at all surprising if these are expressed in a mathematical form. With software, similarly, mathematics is the language used for specifying program modules.

The reason why many find this surprising, even impossible to accept, is that their view of mathematics is too limited. Mathematics is not just about numbers. It is about any formal, logical system with precise rules of operations. The mathematics of the software engineer is not the mathematics that most people used to learn at school. There is no need to solve differential equations, compute logarithms, sines or cosines or even to use that most famous of all mathematical symbols, the number π. Instead we use the calculus of propositions, evaluate expressions in Boolean algebra and collect objects together into sets.

For much of the time only two numbers suffice, the numbers 1 and 0, which can be interpreted as the equivalents of 'true' and 'false'. Many of the concepts are exceedingly simple and are now taught in primary schools; but to the uninitiated,



The structure of the course.

p ∧ q - r is easy to understand once you knows the language, but is incomprehensible otherwise. Unfortunately many very competent computer programmers have never met this sort of mathematics. For them, software engineering is a closed book.

It was for this sort of person that we wrote the training package *Essential Mathematics for Software Engineers*. It consists of three programmed learning texts, each having three blocks; a fourth volume contains a glossary; there is a bibliography and a guide to the course and a video cassette, which introduces each of the blocks and explains some of the concepts in a more graphic way than is possible in a straight text. The first and last blocks are an introduction and postscript to the other seven; blocks two to six introduce the various mathematical concepts, while blocks seven and eight are extended case studies.

Block two looks at sets and logic. The purpose of this is to provide a framework for writing down the essential facts about a problem in an unambiguous way and with the structure clearly visible. What we need is to find simple ways to put together sentences so that is is easy to check whether they are true or false, and to specify sets in such a way that if we take any particular object we can tell easily which sets it belongs to.

We may well ask why, when most of the ideas are so simple, we cannot just write specifications in ordinary English. The answer is that often we can, but English has a number of peculiarities that can lead to ambiguities. The simplest of these is the use of the word *or*. If your are asked at breakfast in a hotel whether you would like cereals or orange juice, which of the following do you state as your choice?

(a) Cereals
(b) Orange juice
(c) Both
(d) Yes please

Here is another example:
"Peter and Andrew were fishermen".
The statement can be paraphrased as (Peter was a fisherman) and (Andrew was a fisherman) but
"Peter and Andrew were brothers", although of exactly the same grammatical appearance, cannot be paraphrased as (Peter was a brother) and (Andrew was a brother). Once again our everyday language is not precise.

The next example is a little more subtle. An advertisement for a used car proclaims "only one careful driver." Let us try to be precise. Let D be the set of all drivers of the car. Let CD be the subset of this consisting of all careful drivers of the car. Then we wish to say that the set CD has only a single element. That, at least, is what it seems to mean. But is that what is really intended? Would you buy a car which had had only one careful driver, and not worry about all the other, careless drivers which the car had had? Or does the advertisement imply that the set D has only one element, and that that driver was careful? I suspect that most people would assume that the second interpretation was the correct one.

Contrast this with the assertion "The car has had only one serious accident." The grammatical structure is identical, yet most people would take the other interpretation, namely that the number of serious accidents suffered by the car is one, but that there may have been other, non-serious ones. Where the same grammatical structure can mean quite different things according to the context, there is a clear indication that the language we are using to specify the structure is not good enough for the purpose.

Block three looks at functions. These correspond to an idealised computer program which has the structure:
Input — Process — Output
In the block we look at how the input and output are specified and how the process relates the two. Functions themselves can be put together in different ways and this provides valuable insight into how programs can be structured using smaller modules.

Recursion and list

Block four brings us to the related concepts of recursion and list. A list is rather like a set, except that the elements of it are in a specific order instead of merely being somewhere in the set. It is possible to insert and delete elements and to sort and merge lists. Recursion is involved because it turns out to be more convenient to define a list in terms of other, shorter, lists. The definition of a concept in terms of itself is called a recursive definition. At first sight it looks like cheating, but it is quite respectable if properly used and often leads to much shorter, easier programs that leave much less scope for error.

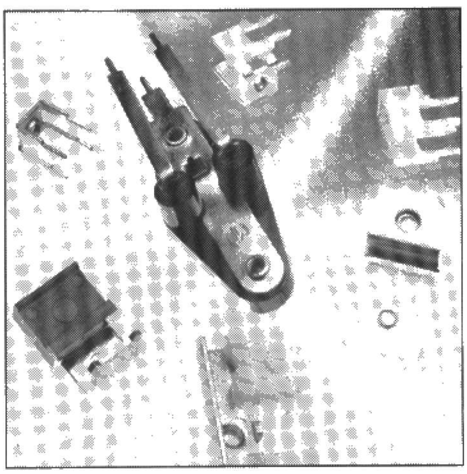
For example, suppose we have two lists of people, both sorted alphabetically, and we wish to merge them into one list. Using recursion we start by comparing the first elements of the two lists.

Whichever one comes first alphabetically we write down and remove it from its list. Now *merge* (this is the recursive step) the two remaining lists by repeating the process and write the merged list after the element we have written down already. That is all, or nearly all. We must also explain what happens if one of the lists to be merged is empty. In fact it is easy: we just write down the other.
The next block is to do with relations. This is not about brothers and sisters, aunts and uncles, though these are used as an example to explain the idea. The point is that mathematics is concerned not primarily with objects, but rather with the relationships between them. Programming too is about relationships, especially between the inputs to a program and the associated outputs. Relations are at the heart of the specification process, just as functions relate to the implementation of the program, and it is vital to have a clear understanding of these two concepts.

Proofs

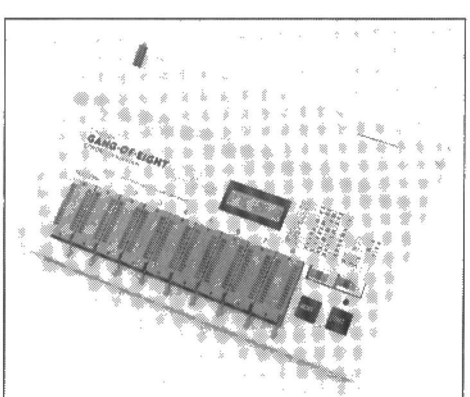
The final mathematical block deals with proofs. Part of the reason for using mathematics for program specification is that it not only helps to eliminate errors in programs, but even holds out the hope that we could *prove* our programs to be correct. This subject is still very much in its infancy, but the fundamental notions that would be needed in any such project are well known to mathematicians.
Blocks seven and eight, as I have mentioned, are extended case studies. One common example that was used to illustrate many of the ideas in blocks two to five was the monitor screen of a computer. In block seven much of this material is pulled together to show how to design a simple text editor, specifying its properties using the mathematical language already developed. It falls far short of a full wordprocessor, but it does illustrate the techniques which could be used to design one. Block eight is a quite different problem. It is the design of an electronic diary system for a small organisation that holds meetings at regular intervals and needs to find when the people who matter are free.
The package has been produced with financial assistance from the Alvey Directorate in the UK and was written by a team from Sheffield City Polytechnic; the Hatfield Polytechnic; the University of Technology, at Loughborough, and ICL. The video cassette, which is of exceptionally high quality, was produced by the Open University and the BBC. Publishers of the complete package are the Institution of Electrical Engineers, whose address is P.O. Box 26, Hitchin, Hertfordshire SG5 1SA, England.

NEW PRODUCTS



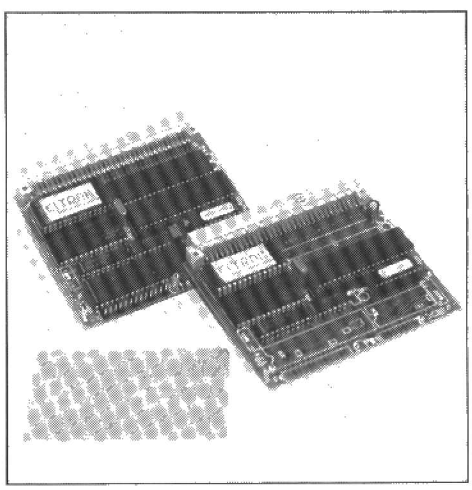
Low-cost transistor sockets

A comprehensive range of low-cost transistor sockets and holders that meet many application needs offer contact resistance of <30 mΩ, insulation resistance of >500 MΩ at 500 V d.c., and an insertion force of <3 kg.
Watts International Components Ltd • Suit 6 • Wyvern House • 46-48 High Street • BOGNOR REGIS PO21 1SP.



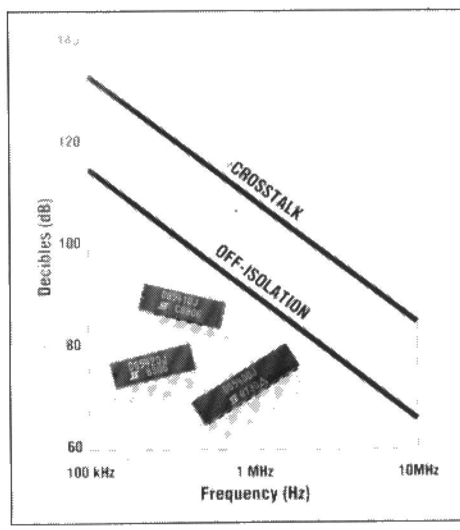
Gang-of-eight relaunch

Dataman has relaunched its production programmer, the Gang-of-Eight. The latest version comes as standard in a robust steel case with a bi-directional RS232 serial interface that facilitates programming via a PC. The new version will handle 2516, 2532, and 2564 EPROMs, as well as all 27 series from 2716 to 27512.
The new programmer retails at £ 395 and has a three-year parts and labour warranty.
Dataman • Lombard House • Cornwall Road • DORCHESTER DT1 1RX.



Microcontroller boards

Eltrak's EIM052 and EIM06 microcontroller boards can save you a lot of time and money. These fully tested, single-board controllers that will interface with your circuitry can be programmed in a high-level language residing on board an can expand the facilities available by the use of 'plug in' devices or compatible expansion boards, thereby tailoring the microcontroller to suit your product needs. This reduces hardware, software, and development equipment costs.
The EIM052 board provides a cost-effective method of installing a 'black box' microcontroller in low-volume products. Each EIM052 has its own simple development system on board. All that is needed to write, test and save a program is a terminal.
For higher volume products, the EIM06 is a more cost-effective solution. This board, which has a range of options, has additional on-board devices to (1) increase the number of I/O lines, (2) add a keyboard, (3) introduce an LCD alphanumeric or graphical display, (4) add a backed-up real-time clock, and (5) add a back-up memory.
Eltrak Electronics Ltd • Monifieth Business Centre • South Street • Monifieth • DUNDEE DD5 4PJ.



500 MHz wideband/video ICs

Three new wideband/video ICs from Siliconix provide widely use quad and dual analogue switch functions for high-frequency operation. Built with combined D/CMOS technology and designed with internal switches in a 'T' configuration, these TTL-compatible ICs provide high off-isolation (—80 dB at 5 MHz) with the widest bandwidth (up to 500 MHz) of any monolithic devices abailable today. They offer reduced crosstalk (—85 dB at 5 MHz), provide lower power consumption, and use less board space than commonly used discrete solutions.
The DG540, DG541, and DG542 are intended for use in audio, video, computer, telecom, military, and industrial systems where wide bandwidth, accurate signal transfer, and circuit density are important.
Siliconix Ltd • 3 London Road • NEWBURY RG13 1JL.

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All prices shown are net and customers in the UK should add VAT where shown. ALL customers must add postage and packing charges for orders up to £15.00 as follows: UK, £1.00; Europe, £1.50; other countries, £2.00 (surface mail) or £3.00 (airmail). For orders over £15.00, but not exceeding £50.00, these p&p charges should be doubled. For orders over £50.00 in value, p&p charges will be advised.

Software is also available from **TECHNOMATIC LIMITED** (for address, see inside front cover).

In Sweden, printed-circuit boards should be ordered from
ELECTRONIC PRESS
Box 63
S-182 11 Danderyd
Telephone: 08-753 03 05

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LETTERS

Letters of a general nature, or expressing an opinion, or concerning a matter of common interest in the field of electronics, should be addressed to The Editor. Their publication in *Elektor Electronics* is at the discretion of the Editor.

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Although we are always prepared to assist readers in solving difficulties they may experience with projects that have appeared in *Elektor Electronics* during the PAST THREE YEARS ONLY, we regret that these can not in any circumstances be dealt with by telephone.

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302 Circuits	**£6.25**
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Elektor Electronics binder	**£2.95**

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Preamplifier for purists	880132-F	8.25	1.24
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1 × 27C64	571	10.00	1.50
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Transmission & reception of RTTY	XSS-100	8.00	1.20

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Readers who wish to make their own PCBs (for private and personal use only) may in many, but not all, cases receive the relevant drawings free of charge by ordering these on the order form above and enclosing a stamped addressed envelope (preferably 9 × 6 in or 230 × 150 mm). These drawings may also be supplied on film priced at £1.00 each plus p&p.

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	880016-3	15.00	2.15
	880016-4	0.75	0.11
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	No.	Price (£)	VAT (£)
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	880120-2, 880120-3	10.00	1.50
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	880132-2	12.25	1.84
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	880092-4	6.45	0.97
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	880163	4.85	0.73
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Evening on the planet Oldana, as the Maplin Juggertrain thunders along the highway; captured on canvas by galaxy famous artist Lionel Jeans and featured on the cover of the new Maplin Catalogue.